Current Research '89

NATIONAL WATER RESEARCH INSTITUTE

Notice is hereby given that mention of any product or material in this publication is not to be taken as indicating that the National Water Research Institute (NWRI) in any way approves, recommends or endorses any such product or material. No mention shall be made of NWRI or of this publication in any advertising, sales promotion, reports, or other written or graphic material which would indicate or imply that NWRI approves, recommends or endorses any product or material mentioned herein, or which has as its purpose an intent to use the name of NWRI of this publication as means, directly or indirectly, of causing, aiding or enhancing the sale or use of any such advertised product or material.

CURRENT RESEARCH '89

A SYNOPSIS OF THE 1988-1989 RESEARCH PROGRAM

AT THE

NATIONAL WATER RESEARCH INSTITUTE

National Water Research Institute
Inland Waters Directorate
Conservation and Protection
Environment Canada

Publication disponible en français sur demande

90-03336/

Detailed information on the research projects at NWRI is available from the Research Branches or the Science Liaison Division. "Reflections 1988-1989", the Executive Director's annual report to the public, and "NWRI Digest", a quarterly newsletter on the activities of the Institute, are also available upon request. Please contact:

National Water Research Institute
P.O. Box 5050
Burlington, Ontario, Canada
L7R 4A6
Telephone: (416) 336-4884

The paper used in this publication contains recycled fibers and is uncoated to facilitate recycling.

TABLE OF CONTENTS

Page

INTRODUCTION 1

LAKES RESEARCH BRANCH 3

Nutrient-Contaminant Interactions Project 4
Sediment-Water Interactions Project 6
Air-Water Interactions Project 8
Nearshore-Offshore Interactions Project 10
Lakes Restoration Project 12

RIVERS RESEARCH BRANCH 15

River Modelling Project 16
Contaminants-Pesticides Project 18
Long Range Transport of Airborne Pollutants Project 20
Ecotoxicology Project 22
Groundwater Contamination Project 24

RESEARCH AND APPLICATIONS BRANCH 27

Analytical Chemistry Project 28
Hydraulics Project 30
Quality Assurance Project 32

NWRI ORGANIZATION CHART 34

PUBLICATIONS AND SCIENTIFIC STAFF 35

NWRI Management Team 35
Lakes Research Branch 35
Rivers Research Branch 39
Research and Applications Branch 44
Research Support Division 46
Science Liaison Division 47
Journal Editorships 47

INTRODUCTION

D. L. Egar
Executive Director
National Water Research Institute

It is with great pleasure that I introduce CURRENT RESEARCH '89, a synopsis of the research activities and publications of the National Water Research Institute (NWRI) during 1988-89. This is the second edition of Current Research and I hope it will provide our Canadian and international water research colleagues with a useful overview of our progress in the past year.

Our continuing goal at NWRI is to demonstrate leadership in developing the scientific knowledge and expertise required by Environment Canada to resolve important Canadian water management issues. Our present research strategy emphasizes investigations into the critical ecosystem interactions which control the fate and effects of pollutants, improved understanding of the dynamics of important regional ecosystems, and the development of better aquatic assessment and prediction methodologies.

Research at NWRI is conducted within multidisciplinary project groups, each of which addressing the science dimension of an emerging or priority water issue. In the following pages, Project Chiefs from the three Research Branches summarize the objectives and highlights of their research teams. Their reports are necessarily brief, but I believe they clearly show that the Institute's talented scientists, technicians and support staff are committed to the creation of new knowledge of scientific merit and practical importance. A comprehensive listing of staff publications is also provided.

The year 1989 saw a deepening of the global environmental crisis. At the same time, however, a broader acceptance emerged of the concept of sustainable development as the basis for developing an agenda for future change. Water is both an integrator of environmental change and an engine of economic growth and, as such, is a key to progress. Better management, however, can only come with better scientific knowledge. NWRI, with its specialized expertise, understanding of Canadian aquatic ecosystems and access to knowledgeable researchers around the world, is well positioned and eager to contribute constructively to this common effort.

LAKES RESEARCH BRANCH

R. J. Allan, Director

The Lakes Research Branch conducts applied research to provide effective management options for the conservation and protection of Canada's freshwater lakes. The research program encompasses natural lakes and man-made impoundments throughout Canada as well as the large, freshwater-dominated, upper estuaries of major rivers, particularly the St. Lawrence and Fraser rivers. Although emphasis is on the Laurentian Great Lakes, study sites are located throughout the country.

Research is conducted into significant limnological processes, and the chemical, biological and physical factors that affect their rates. Emphasis is placed on the sources, fate and effects of pollutants, particularly toxic organic chemicals, as well as on metals, radionuclides and nutrients. The influence of lake trophic state on toxic chemical fate and effects is a major area of interest because of the potential need to integrate existing nutrient control programs with plans to control both future toxic chemical loadings and the effects of previous releases. An important general goal is to quantify the transfer of materials (toxic chemicals, nutrients, sediments, gases) across limnological interfaces such as those between sediments and water, air and water, and nearshore and offshore water masses. Investigating the potential for modifying these transfer processes and their effects, through *in situ* treatment, is also a high priority. Some of the issues being researched include:

- assessment of long-term water quality trends;
- external and internal loadings of pollutants;
- sources, transport and movements of water masses and their associated particulate loads;
- partitioning of pollutants between media in the water column;
- partitioning of pollutants between the water and the atmosphere;
- burial of contaminants in bottom sediments;
- sedimentation versus resuspension rates;
- biological mixing of sediments;
- degradation and biological uptake of pollutants;
- food chain transfer by benthic organisms of sediment-associated pollutants;
- evaluation of ecosystem health;
- water quality impacts of climate change;
- influence of wetlands on climate change;
- rehabilitation potential of lakes and reservoirs;
- in-lake restoration methods;
- manipulation of aquatic food chains.

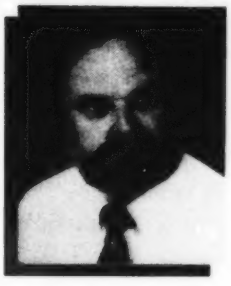
Providing predictive models for all the above issues is the ultimate goal of the research program.

The research studies in the Lakes Research Branch are organized into five multidisciplinary projects: **Nutrient-Contaminant Interactions; Sediment-Water Interactions; Air-Water Interactions; Nearshore-Offshore Interactions;** and **Lakes Restoration.**

Our research results are used by national and provincial water management agencies in Canada and by national agencies in other countries involved with water quality protection and conservation. In the Great Lakes, part of the effort from the Branch supports the research and technology transfer needed to develop Remedial Action Plans for the 17 Canadian Areas of Concern. These programs help to fulfil Canada's obligations under the Great Lakes Water Quality Agreement (GLWQA) between Canada and the United States.

NUTRIENT-CONTAMINANT INTERACTIONS PROJECT

J.H. Carey, Project Chief



Introduction

The Nutrient-Contaminant Interactions Project is investigating the influence of lake trophic status on contaminant dynamics and impacts in lakes. Although the primary goal of the work is to improve our knowledge of contaminant pathways in the Great Lakes, much of the work is conducted in a series of mostly headwater lakes centred around a field site near Bancroft, Ontario, known as the Model Lakes Ecosystem Study (MODLES). This region is an area of transition between igneous and sedimentary bedrock and therefore lakes with differing chemical compositions are available for study. The atmosphere is the single major source of contaminants. A multidisciplinary approach is taken in an attempt to characterize and quantify critical processes.

The research program examines the general hypothesis that trophic state interacts with contaminants by influencing contaminant bioaccumulation (and subsequent effects), degradation and distribution. The objective of the project is to identify the key variables that can be used to predict contaminant bioaccumulation, degradation and sedimentation in lakes and to apply these findings to the Great Lakes.

Specific research activities include the following:

- investigation of the relationship between trophic status, community structure and relative importance of benthic versus planktonic uptake routes for contaminants;
- investigation of the relationship between nutrient availability in lakes and lipid content in aquatic organisms and examination of resultant effects on bioaccumulation and translocation of contaminants;
- examination of the physiological responses of aquatic organisms to extremes of nutrient availability and subsequent effects on contaminant bioaccumulation;
- investigation of the effect of dissolved organic matter on contaminant pathways and the influence of trophic status on the relative importance of various sources of this dissolved organic matter.

Research Highlights

● Analyses of organochlorines in zooplankton from over 30 MODLES lakes are now complete. The inverse relationship between spring total phosphorus and total PCBs reported last year, based on initial results, has now been confirmed with other organochlorines, notably those related to chlordane and DDT (Figure 1). Correlations are improved when zooplankton number is considered. Thus, it appears that factors affecting zooplankton abundance, such as the ratio of lake surface area to mean depth, also affect contaminant concentrations. Seasonal effects on lipid production and speciation were investigated in five MODLES lakes from April to November. Lipids were analyzed as classes, such as phospholipid, triglycerides, etc. Samples will be analyzed for contaminants in the coming year.

● Dissolved organic matter (DOM) was isolated from six MODLES lakes, two freshwater marshes, a humic bog and three sites on the Bay of Quinte. DOM was fractionated by size, and isolated material was analyzed for ash, carbohydrate, protein, nitrogen and iron. The results indicated that in lakes the amount of DOM derived from autochthonous sources is higher than was commonly assumed, suggesting that use of humic acids as "model" DOM in laboratory experiments may be inappropriate. Collaborative research with McMaster University on the characterisation of the isolated material and with the Canadian Centre for Toxicology on its effect on pesticide bioavailability was initiated during the year.

● The effect of herbicides on algal uptake of ^{14}C was studied using plankton samples from two MODLES lakes and Lake Erie. The herbicides primarily affected the smallest size ranges of algae. Since these size ranges are those utilized by zooplankton as food, the results may have significant implications for community structure in lakes receiving agricultural runoff.

● Anaerobic degradation in sediments from five MODLES lakes was investigated in the laboratory. Degradation of model aliphatic chlorinated compounds were observed in all samples, but degradation of model chlorinated aromatics were slow. There were no striking differences among different lake sediments. New experiments involving nutrient additions and sediments from eutrophic areas are planned.

● Studies on the photochemical production of reactive intermediates capable of participating in abiotic contaminant degradations continued. The photolytic production of hydrogen peroxide in eight MODLES lakes and Lake Erie was investigated. Diurnal patterns suggested that hydrogen peroxide concentrations in surface waters were controlled by the relative kinetics of the production and degradation processes. Biologically mediated degradation of H_2O_2 appeared to be an important process.

● The fungal community in sediment from six MODLES lakes was characterized by dilution plating techniques. In sediments from deeper mid-lake regions, the fungal community was dominated by two moulds, one of which appears to be a previously unidentified species. Of the two most common yeast species, one of these also appears to be a new species. Samples from shallow, nearshore regions differed from the deeper samples by having a more diverse fungal community, presumably reflecting terrigenous influences.

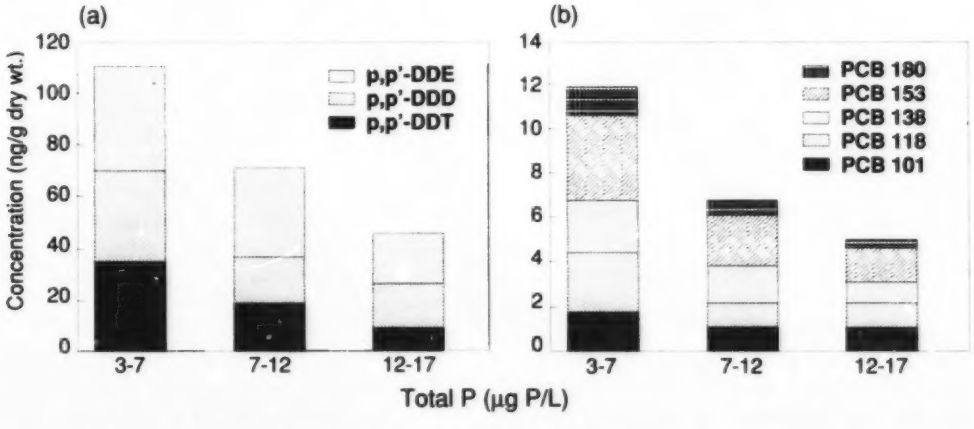


Figure 1. *Average concentrations of (a) DDE, DDD and DDT, and (b) five PCB congeners in zooplankton for lakes grouped according to their total phosphorus concentrations in spring.*

SEDIMENT-WATER INTERACTIONS PROJECT

A. Mudroch, Project Chief

Introduction

Many contaminants discharged into aquatic ecosystems become associated with bottom sediments. Consequently, sediments act as sinks as well as *in situ* sources of persistent hydrophobic toxic organics, metals, radionuclides and nutrient contaminants. These contaminants can be recycled into water and therefore become available for accumulation in the food chain. In the aquatic environment, the contaminants and nutrients are distributed among the aqueous phases (water column and sediment pore water), suspended and bottom sediments, and biota. Transport of contaminants among these different compartments is affected by environmental conditions in the sediments near the sediment-water interface and may vary from one system to another (Figure 2).

The objective of this project is to quantify the interactions and transport of contaminants between individual sediment components in order to evaluate their relative importance. The ultimate goal of the project is to model contaminant effects in lake systems for long-term management planning, policy formulation and selection of adequate measures for contaminated sediment remediation.

Research Highlights

- In Lake Ontario, the concentrations of lead in sediments from the depositional basins have decreased since 1974 from about 200 µg/g to about 100 µg/g. This trend reflects the effects of reduction of leaded gasoline consumption in the United States and Canada, and suggests that natural burial of contaminated sediments by cleaner material entering the lake is relatively efficient.

- The release of contaminants from polluted sediments disposed in confined disposal facilities (CDFs) was investigated. The results showed that the concentrations of metals in vegetation collected at these CDFs exceeded normal levels found in urban foliage at several locations. Smartweed, clover and grass, however, accumulated lower concentrations of Cd, Cr, Cu, Ni and Zn than sedge and, consequently, they appear to be more suitable for colonizing polluted sediments in confined disposal facilities.

- Polyaromatic hydrocarbons (PAHs) are considered priority pollutants. They are formed and released in the environment from different sources. In the Mackenzie River, the composition of PAHs in water and suspended sediments indicated that the principal source of PAHs was from combustion processes. In Hamilton Harbour, the greatest concentrations of PAHs (up to over1000 µg/g) were found in sediments of an area adjacent to the industrialized southern shore of the harbour.

- Radionuclides released under an accidental minor discharge from the Chalk River nuclear laboratories were used to trace the transport of contaminants through the Ottawa-St. Lawrence River system. It was estimated that these radionuclides reached Ottawa in about 40-45 days. It took an additional 15 days for them to reach Montreal, via the Ottawa River, and another three days for them to be transported to Quebec City. This is the first available estimate of the time for transport of material through the Ottawa-St. Lawrence River system.

- Contaminants associated with particulate matter inputs and transport of contaminants, including radionuclides, were investigated at Port Hope, Lake Ontario. Sediment geochemistry and concentrations of contaminants in suspended and bottom sediments suggested that recent inputs, rather than resuspension of harbour sediments, are responsible for the accumulation of contaminants in suspended matter in the harbour.

● Elevated levels of sediment contaminants (especially metals) and depressed benthic fauna populations occur at the mouth of the Spanish River, North Channel, one of the identified Areas of Concern in the Great Lakes region. Results of a study conducted at the site showed an impoverished benthic fauna, both in number of species and in abundance. The distribution of the benthic fauna was inversely related to concentrations of Ni, Cu and Zn in sediments.

● Radionuclides originating from the West Valley, New York, are transported by the Niagara River and deposited in the bottom sediments of Lake Ontario near the mouth of the Niagara River. Pu-239/240 and Am-241 originating from the West Valley account for 36 and 80 percent, respectively, of the total inventory of these radionuclides deposited in this area.

● A numerical model for seepage erosion of lake shore bluffs was developed and verified with data from the north shore of Lake Erie. The model will be applicable to the evaluation of the erosion of shore bluffs at the low-level radioactive waste disposal site near Port Granby, Lake Ontario.

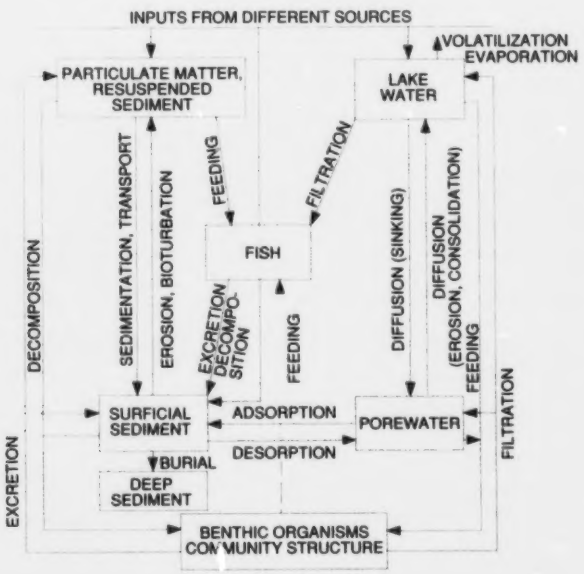


Figure 2. *Processes studied by the Sediment-Water Interactions Project.*

AIR-WATER INTERACTIONS PROJECT

W.A. Glooschenko, A/Project Chief

Introduction

Atmospheric depositions often represent a major source of inputs of contaminants, both inorganic and organic, to aquatic ecosystems. Interactions between the air and aquatic ecosystems, including lakes, rivers and wetlands, are therefore of extreme importance.

Global climate warming is another major concern which could have significant effects on aquatic ecosystems. Lake thermal regimes are likely to be modified, with resulting effects on nutrient cycling, oxygen conditions, chemical budgets and the ecology of biota. Recent interest in the global budget of greenhouse gases, e.g., carbon dioxide and methane, has raised questions about the role of Canada's vast northern wetlands in the production of greenhouse gases and therefore on climate change.

The present research objectives of the Air-Water Interactions Project include studies related to both the cycling and deposition of organic contaminants and metals and to climate change.

Research Highlights

● A multi-agency research program, the Northern Wetlands Project, involving NWRI, Canadian and U.S. government agencies, and six Canadian universities has been initiated to study the exchange processes of greenhouse gases (e.g., methane) between air and surface in northern wetlands. Methane is formed mainly by anaerobic biological processes and little is known about the contribution of lakes and wetlands to the global methane budget. The research program has three major components. The first is a cooperative study with NASA to measure fluxes of methane and other gases over the Hudson Bay Lowland. Different aerial and land-based techniques will be used over a 100-km^2 grid in the Kinoje Lake area. The second component of the program is the establishment of a "chemical observatory" which will be used to gather long-term air chemistry and climatological data. The third part of the program will focus on the development of a gas exchange model for wetland regions. The model will be used in the future for climate impact assessments. The Northern Wetlands Project is receiving major funding from the Natural Sciences and Engineering Research Council.

● In collaboration with the Hydraulics Project, a 30-metre gas transfer flume has been constructed for experimental studies of the transfer of toxic chemicals across the air-water interface (Figure 3). Preliminary experiments with chlorobenzene have shown a strong dependence of the mass transfer coefficient on wind velocity. Mass transfer coefficients will be compared to a variety of measures of the turbulence in the gas and liquid phases to better understand the processes controlling the movement of toxic organic chemicals across the air-water interface.

● Studies have been done on precipitation chemistry at five sites in Western Canada and samples are now analyzed for organic contaminants. A master sampling station was established at Point Petrie, Lake Ontario, in cooperation with the Atmospheric Environment Service, for studies of atmospheric deposition of contaminants in Lake Ontario. Little information has been obtained in the past from this area. An all-weather precipitation sampler was constructed and is currently being tested. Water and suspended sediment samples were also collected from major tributaries of Lake Ontario and were analyzed for contaminants in support of the Lake Ontario Management Plan.

● Moss and litter samples were collected on two transects north of Lake Superior. Intensive replicate samples were also collected in the Thunder Bay area to investigate the use of mosses, litter and peat as biomonitors of atmospheric deposition of metals and organics. Samples are currently being analyzed.

● Development of a paleoclimatic model has been completed. Data on fossil ostracodes recovered from lacustrine sediments were used to extrapolate monthly and yearly air temperatures and precipitation. Cores collected from Turkey Point marsh on Lake Erie and Grenadier Pond (Toronto) are used to study past Great Lakes water level changes over several centuries.

● A review of the potential implications of climate warming on the Lower Great Lakes thermal regime and water quality has been initiated. Current model development has concentrated on the specification of heat and turbulent fluxes required at the lake surface to force thermal and water quality models. Application of the heat flux submodel to detailed analysis of conditions occurring during an anomalously "warm" year has provided a description of the surface heat flux conditions which contributed to higher lake heat storage and changes to lake thermal conditions (water temperature, ice extent, stratification season and thermocline depth). By analogy, the results provide some preliminary indication of potential lake responses under climate warming due to expected increases in atmospheric greenhouse gases.

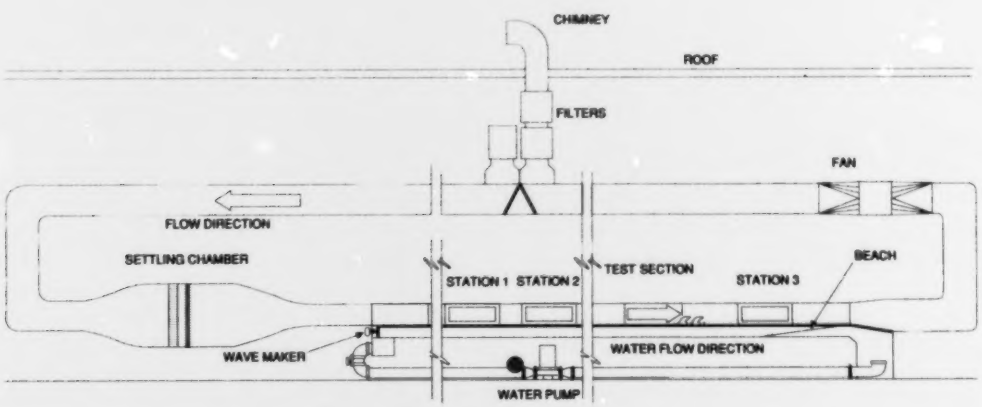


Figure 3. *Gas transfer flume used in experimental studies of the transfer of toxic chemicals across the air-water interface.*

NEARSHORE-OFFSHORE INTERACTIONS PROJECT

K.L.E. Kaiser, Project Chief

Introduction

Most environmental contaminants enter our lakes from local sources, such as effluent pipes and polluted tributaries. Once in nearshore waters, they are dispersed by various mechanisms and a complex array of processes control their pathways, fate and effects.

The general objective of the Nearshore-Offshore Interactions Project is to resolve existing uncertainties about the predominant rate-controlling processes that determine the pathways, effects and fate of contaminants. Specifically, the project combines chemical, physical, statistical and limnological expertise to assess these processes. Modelling is a major activity, including both physical hydrodynamics and chemical structure/biological effect relationships. Research is conducted mainly in the riverine lakes and the estuary of the St. Lawrence River and in the Niagara River/Lake Ontario system.

Research Highlights

- A review of the effects of over 500 chemicals on the microorganism *Photobacterium phosphoreum*, commonly used in the Microtox test, has been published. This exhaustive compilation of literature and in-house data will be useful for the interpretation and prediction of the effects of environmental contaminants.

- Molecular electron density shifts in para-substituted aniline and nitrobenzene derivatives showed high correlations with the acute toxicity of these compounds computed *ab initio* (i.e., from molecular framework with standard element parameters) in the Microtox test. These results confirm and extend our ability to predict biological effects from chemical structure.

- Data collected at over 20 stations throughout the St. Lawrence River, between Kingston, Ontario and Quebec City, show that significant amounts of PCBs and other organochlorine contaminants are derived both from Lake Ontario and from other sources along the river. The riverine lakes in the St. Lawrence do not appear to retain contaminated sediments beyond a seasonal cycle. These results were presented at the First International Symposium on the "Fate and Effects of Toxic chemicals in Large Rivers and their Estuaries." These data are the first set of contaminant values in critical aquatic compartments determined for the entire river and the Ottawa River tributary.

- Studies using current meters and Lagrangian drifters in the Kingston Basin of Lake Ontario showed that 45 percent of the St. Lawrence River flow is through the north channel and 55 percent through the south channel as divided by Wolfe Island. The Kingston Basin acts hydrodynamically independent of Lake Ontario and has a circulation structure with two hydraulic streams and two large-scale counter rotating eddies on either side of these streams.

- The development and application of various computer models for aquatic systems continued. In collaboration with the Ontario Ministry of the Environment (MOE), a model for the Toronto waterfront was created by coupling the organic contaminant fate and pathway model, TOXFATE, developed at NWRI, with a hydrodynamic model developed by the Rand Corporation. Results of the model are given in the form of hazard plumes (Figure 4).

- The predictive capacity of the TOXFATE model was verified using new field data on PCB concentrations from Lake Ontario. This model relates loadings to concentrations of PCB in water, sediment and fish, and predicts the responsiveness of the lake to various loading scenarios. The same model was also applied to the Rhine River (Europe) to describe the fate and effects of a major chemical spill which occurred in 1986.

- Significant progress was also achieved in the area of contaminant/site ranking by developing an expert system compatible with the Vector Scoring System (VSS) proposed by MOE. The resulting software ranks contaminants on site according to many criteria, tests or attributes (weighted or unweighted), identifies contradictions and determines the most critical criteria in the ranking scheme, thus identifying redundant information and contributing to cost reductions in data collection.

- Mathematical modelling of the water exchange between Hamilton Harbour and Lake Ontario through the Burlington Ship Canal was achieved with historical summer flow data. Winter and spring time exchange data are being collected, in collaboration with the Water Survey of Canada and private industry, using a new acoustic measuring device, both to test the device and to determine the influence of meterological and shipping events on canal flow.

- Project staff made significant contributions to reports of the binational Upper Great Lakes Connecting Channels study, particularly those on Lake St. Clair and the Detroit River. These reports summarize and synthesize the available scientific data for each of the geographical areas and give recommendations for remedial activities and further studies.

- Inventories were prepared on the global values of natural and anthropogenic emissions of trace metals to the atmosphere and into soils and the aquatic environment. Results of these budgets were published in the journal *Nature* and demonstrate that man's influence on the global cycling of most trace metals has become significant.

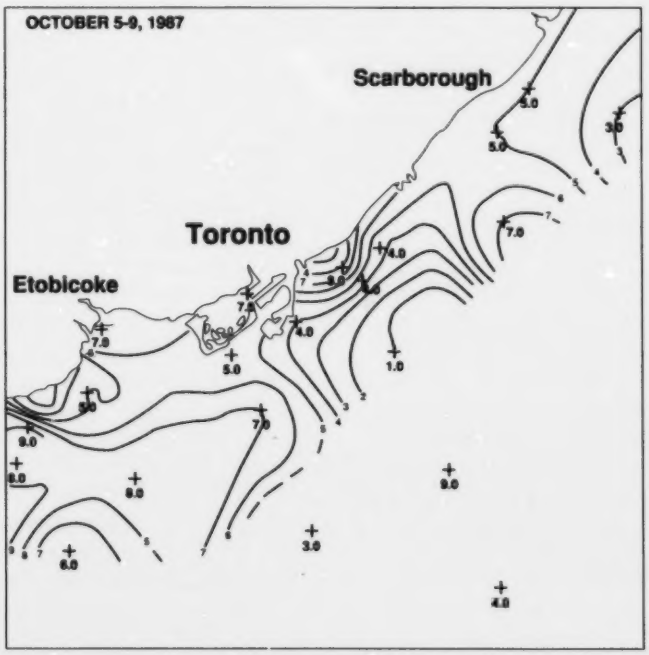


Figure 4. *Idealized risk isostats along the Toronto waterfront in Lake Ontario. Higher values indicate higher risk. Computations are based on the concentrations of 29 toxic chemicals in water samples collected from October 5-9, 1987.*

LAKES RESTORATION PROJECT

M.N. Charlton, Project Chief

Introduction

Lakes, reservoirs and embayments in large water bodies do not always respond adequately to pollution controls implemented to attain specific water quality objectives. Such situations can be caused by the presence of contaminated sediments or by continuing input of pollutants from uncontrollable diffuse sources in the drainage basin or from the atmosphere. Other problems for water use can be the invasion of aquatic weeds, siltation and oxygen depletion.

Effective management of such water bodies may require basin-wide land use controls, which can take many years to implement, or they can be tackled directly by *in situ* treatment. The long-term goal of this project is to identify critical geochemical processes that can be manipulated so that *in situ* remedial technologies for the practical restoration of lakes and reservoirs can be devised, evaluated and implemented. Particular emphasis is currently placed on Areas of Concern in the Great Lakes, especially Hamilton Harbour, but several studies are ongoing in Western Canada and in smaller lakes in Ontario.

Research Highlights

- Suspended particles caught by sediment traps in Hamilton Harbour are just as contaminated as samples of surficial sediments. Some samples are even more contaminated than bottom sediments. Surface layers of contaminated sediments are therefore not buried by a layer of new uncontaminated material. At some sites, however, the surface sediment is less contaminated than lower subsurface material, suggesting that a gradual and natural recovery process is occurring. The distribution of contaminants in the traps showed sources of polychlorinated biphenyls (PCBs) in the east end of the harbour, while metals and polyaromatic hydrocarbons (PAHs) are mainly associated with the south and south-east industrial area (Figure 5).

- Sediment toxicity screening with *Daphnia* and *Photobacterium* tests revealed a small area of the Hamilton Harbour heavily contaminated with a tar deposit containing PAHs. As the general distribution of PAHs in the harbour seems related to this deposit, the feasibility of removal of the deposit is being evaluated.

- A modified *Photobacterium* toxicity test was developed to permit the bacteria to remain in full contact with the entire sediment sample. The modified test, in which bacteria are exposed to contaminants bound to sediment particles, is more advantageous than the standard elutriate test.

- Horizontal mixing in Hamilton Harbour is not strong enough to homogenize the harbour water. Ammonia concentrations vary ten-fold across Hamilton Harbour due to loadings occurring only in the east end and to bacterial demand in the summer. Phosphorus (P) concentrations vary only about two-fold. Concentration of soluble P is approximately ten times higher than spring concentrations in Lake Ontario, suggesting that the algae in the harbour are "overloaded" with P. Very large changes in P loading during summer would be required to control algae. Due to slow horizontal mixing, even small sources in the west end, although insignificant compared to total annual loads, may be important to summer water quality.

- Turbidity in Hamilton Harbour is controlled by algal and mineral concentrations. Water clarity in the main harbour and on the north shore is controlled mainly by algal

turbidity and met the minimum standard for swimming during much of 1988. Turbid water in the east and west ends is largely a result of suspended soils and/or mineral material. These findings were used to predict water clarity increases and consequent aquatic plant habitat improvement due to various remedial scenarios. Minor increases in plant habitat can be expected from decreased algal turbidity.

● The Bay of Quinte Remedial Action Plan is concerned with the possibility of sediment phosphorus (P) regeneration once P inputs are reduced. The importance of sediment P in the Bay of Quinte was assessed with measurements of "bioavailable" P. Sediment P seems to be transported out of the area of highest P loads near municipalities. Confirmation of this would mean that sediment P would not prevent local water quality improvement, which depends mainly on further sewage treatment or other ways of reducing summer loads.

● Experiments conducted with the University of Alberta to add oxygen to Amisk Lake, Alberta, were successful in maintaining 5 mg/L during the winter when the lake is usually anoxic. Experiments are continuing during the summer season. Lime addition to control eutrophication was further tested in farm dugouts, and the effects of earlier additions to Figure Eight Lake, Alberta, were monitored. Lime seems to control excessive algae in dugouts, and experiments are now being planned to determine if lime precipitation reactions clear agricultural chemicals (i.e., fertilizers, herbicides and pesticides) from the water.

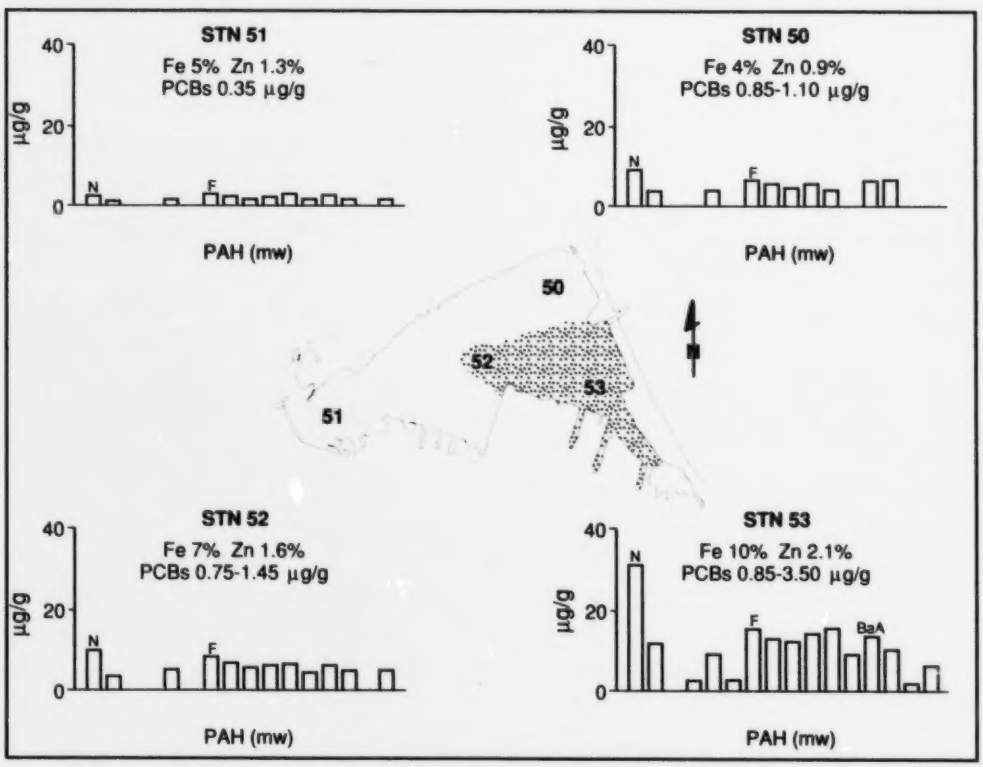


Figure 5. *Iron, zinc, PCBs and individual PAHs in particles caught in sediment traps at four sites in Hamilton Harbour. The results illustrate the greater contamination in the industrial area of the harbour.*

RIVERS RESEARCH BRANCH

E.D. Ongley, Director

The Rivers Research Branch conducts applied research and provides policy advice on a broad range of water resource issues associated with rivers and river basins in Canada. Water resource management in Canada is carried out within the framework of land-water interactions. Rivers receive and integrate the effects of a multitude of anthropogenic activities associated with point sources such as effluents from urban and industrial activities, and non-point sources such as atmospheric deposition, groundwater contamination, agricultural chemicals and urban runoff. Rivers are the primary means by which these impacts are transferred to large lakes and oceans.

The Branch seeks to understand the complex relationships involving physical, biological and chemical interactions in Canadian rivers and drainage systems. This knowledge base is required to meet federal objectives for contemporary and emerging water resource management concerns that have national and international implications.

The Branch is structured around five research projects which address contemporary and emerging national priorities: **River Modelling; Contaminants-Pesticides; Long Range Transport of Airborne Pollutants (LRTAP); Ecotoxicology** and **Groundwater Contamination.** While the projects facilitate multidisciplinary research, they also seek to preserve the critical mass of disciplinary expertise. Individuals often contribute to more than one project and any one project may provide disciplinary expertise to another project.

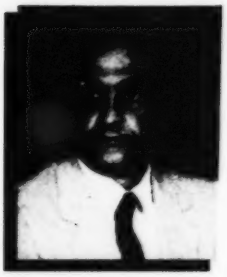
Research and technology transfer activities extend from coast to coast and include such diverse topics as:

- pesticide contamination of groundwater in Prince Edward Island;
- hydrocarbon contamination in Arctic rivers;
- pesticide evaluation;
- acid rain effects and evaluation of mitigation options in Quebec and Atlantic Canada;
- expert systems applications to contaminant pathways in rivers in Ontario and British Columbia;
- water quality monitoring protocols in the Prairie provinces;
- hydraulic and sediment transport issues across the country;
- ecotoxicological R&D and public health issues nationally.

Branch scientists serve on a variety of national and international commissions, associations and committees, and participate in national and international policy negotiations. They travel internationally on collaborative and consultative missions for Canadian and international development agencies and scientific organizations. They also serve as editors, conference chairpersons and organizers for a wide range of international activities. Many hold adjunct faculty positions in universities in Canada and abroad. The Branch also seeks opportunities to improve the competitive position of Canadian environmental industries, both through direct R&D transfer and utilization of international contacts, to identify commercial opportunities for Canadian industry.

RIVER MODELLING PROJECT

S. Beltaos, Project Chief



Introduction

River flow and basin processes and their interaction with water quality are the focus of the River Modelling Project. Emphasis is on runoff processes and transport of contaminants in rivers, on the development of remote sensing capabilities for monitoring important water quality parameters, and on river ice phenomena such as frazil ice and ice jams. Modelling expertise in this project also supports activities in other NWRI projects and there is extensive interaction with the LRTAP Project for expert systems development of acid rain models.

Research Highlights

● Urban runoff is known to transport significant quantities of polynuclear aromatic hydrocarbons (PAHs), but the understanding of underlying processes is limited. In a study co-sponsored by the Ontario Ministry of the Environment under the MISA Program, the major sources of PAHs at Sault Ste. Marie were assessed. Areal deposition was quantified in snowpack. Industry and domestic heating account for 40 percent of the total PAH loadings. PAHs originating from traffic by-products generally settle in the immediate vicinity of roads and account for the remaining 60 percent. Three modes of PAH transport were identified: dissolved in the water; adsorbed onto particles; and dissolved in the organic matter adhering to particles. The last mode explains the observed large levels of PAHs associated with coarse street particles (0.2-1.0 mm).

● The fate of many contaminants in rivers is governed by the hydrodynamic transport of fine sediments, a process complicated by flocculation and consequent alteration of the erosional and depositional properties of the sediment. As a first step toward modelling the transport of flocculating sediment in rivers, the simple case of particle settling in a stagnant water column was analyzed. Comparison of predicted data with experimental data has been encouraging (Figure 6). This appears to be the first model of the settling of fine particles, subject to floc formation, that has been confirmed with experimental data. In addition to predictive analysis, new equipment is being acquired for laboratory and field investigation of fine sediment transport and related biogeochemical processes in rivers.

● Biofilm consumption can be an important mechanism for the removal of contaminants from river systems, especially in shallow, rock-lined streams. An analytical model has been formulated to quantify the processes of advective contaminant transport in the main flow, diffusion through the viscous sublayer into the biofilm and diffusion and reaction within the biofilm. It was shown that the rate of loss of substrate in the main flow closely follows the biofilm kinetics so that the latter can be investigated by measuring main flow concentrations.

● A series of water quality monitoring devices are being developed under the acronym MOMS (multi- or mono-spectral optical monitoring system) to enable remote or direct measurements on inland water bodies. These lake and river MOMS include ship- and bridge-mounted upwelling and downwelling radiometer systems and continuous-flow-through, variable-path-length transmissometer systems. The latter has been designed for indoor, round-the-clock monitoring of sediment concentrations in river water that is continuously pumped past the transmissometer sensors from a fixed point in the river. Field testing is to commence shortly.

● Modelling and prediction of the winter regime of rivers requires an understanding of the formation, transport and evolution of frazil ice, including bottom accumulations known as anchor ice. Problems associated with such ice forms are particularly troublesome to the hydro industry. With operational funding provided by three North American hydro companies, a three-year project was initiated to study the basics of frazil formation and evolution.

● Scientific expertise was provided to major national and international events or projects: project scientists were involved in the organization of the 23rd Congress of the International Association for Hydraulic Research; invited lecture tours were undertaken to USSR, Bangladesh and Pakistan; invited contributions were made to UNESCO; and advice and guidance were provided to the Canadian River Ice Model Project.

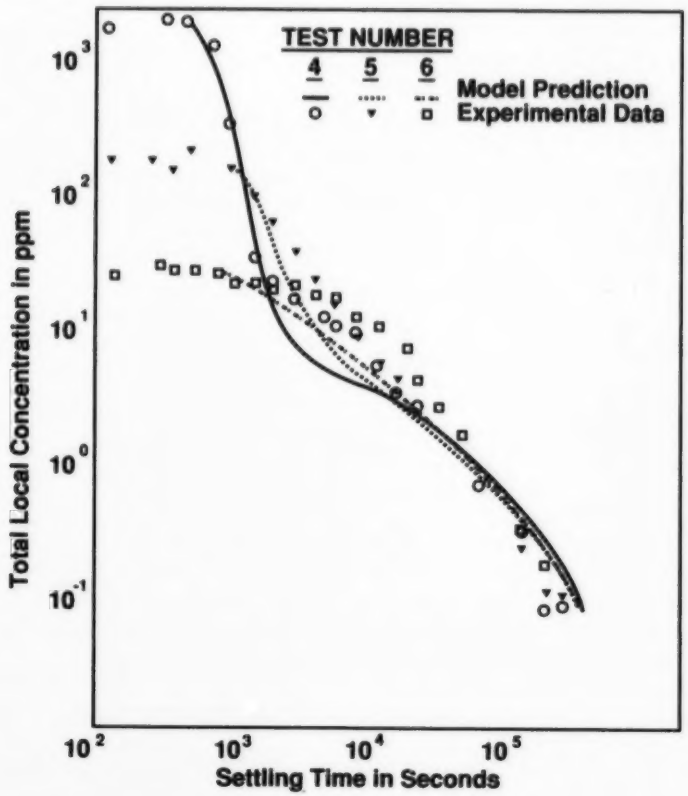


Figure 6. *Change in total sediment (flocculant) concentration in water as a function of settling time.*

CONTAMINANTS-PESTICIDES PROJECT

R.J. Maguire, Project Chief

Introduction

The general objective of the Contaminants-Pesticides Project is to develop knowledge for use by Environment Canada in assessing the hazard posed by toxic chemicals released to Canadian rivers and receiving waters. The hazard of a given chemical to organisms in water or sediment is a function of its concentration, toxicity and persistence. Research is performed in all of these areas and, in conjunction with the Ecotoxicology Project, on the determination of effects of toxic substances on aquatic communities and ecosystems. Research topics are chosen in response to a variety of concerns. These include gaps in the scientific literature, chemicals identified in priority lists for risk assessment (e.g., under the Canadian Environmental Protection Act and the Pest Control Products Act), or in response to regional concerns.

Research Highlights

- The Department of Agriculture announced on February 28, 1989, its regulation of antifouling uses of tributyltin under the Pest Control Products Act. This regulation, which amounts to a limited ban, prohibits the use of tributyltin on vessels of less than 25 m in length. For vessels longer than 25 m, there will be a maximum daily release rate of 4 micrograms of tributyltin per square centimetre of hull surface. It is expected that the Department of Agriculture regulations on antifouling uses of tributyltin will substantially reduce, if not eliminate, the hazards to aquatic organisms in Canada. All the data on the occurrence and persistence of tributyltin in Canadian waters came from NWRI.

- Chlorinated hydrocarbons are usually determined after extraction at neutral pH. Water samples collected on the Niagara River at 43 dates in 1985-86 have been analyzed following organic solvent extractions under acidic and basic conditions. Significant concentrations of PCBs and other chlorinated hydrocarbons, however, have been found in extracts of filtered water samples at pH 12 after the water had been thoroughly extracted at pH 1. The contribution of the basic extract to the total concentration derived from acidic, basic and suspended solid extracts ranged from zero percent (for 31 of the chemicals) to 100 percent (for PCBs 15, 114 and 201, aldrin and p,p'-DDT). Experiments with water from another source showed that some PCBs were also recovered in extracts of basic filtered water which had previously been thoroughly extracted under either acidic or neutral conditions. One explanation for the result may be the formation of a strong association between a fraction of the dissolved lipophilic chemicals and dissolved organic matter, an association that is resistant to organic solvent extraction at acidic or neutral pH, but which is at least partially disrupted by extraction at high pH. These findings suggest that concentrations of chlorinated hydrocarbons in the Niagara River water, determined by extraction solely at neutral pH (the usual technique), may be underestimated.

- Bioconcentration patterns for contaminants in native mussels (*Elliptio complanata* and *Lampsilis radiata*) collected from the St. Lawrence River in 1985 implicate Lake Ontario as the source of mirex and DDT derivatives, while the Grasse River in New York was the major source of PCBs. Numbers of PCB congeners in mussels increased from 21-27 in the upper river to 56-59 in the Cornwall/Massena area, mainly due to the appearance of di-, tri- and tetra-chlorobiphenyls (Figure 7). An average of 43 congeners persisted in mussel tissues as far downstream as Lake Saint-Pierre.

● Intracellular tissue concentrations of free amino acids (FAA) were monitored in caged mussels (*Elliptio complanata*) exposed *in situ* in the Yamaska River, Quebec, and some of its tributaries. Total concentrations of FAA increased in the mantle and adductor muscle tissue at sites exposed to agricultural runoff and effluent from light industry and sewage treatment plants. These same sites were ranked from poor to very poor in water quality using a biotic index based on benthic invertebrate communities. Condition indices were not correlated with changes in total FAA. Significant decreases in condition indices were observed only at sites downstream of municipal sewage outfalls. Increases in total FAA in some tissues of freshwater biota may thus be indicative of generalized stress brought on by a variety of factors and may be useful as a biochemical index of toxicity. More research to determine cause-and-effect is required.

● The toxicity of metal mixtures to algae was examined. A mixture of ten metals, each at its non-toxic Great Lakes water quality objective level, was extremely toxic to several species of algae and natural phytoplankton. The metal mixture reduced primary production, reproduction and enzyme activities. Factorial analyses of various metal combinations indicated both synergistic and antagonistic actions. The zinc-copper combination was the most toxic identified. Fractionation of natural phytoplankton from Lake Ontario indicated that ultraplankton (size <10 µm) were the most sensitive organisms to metals. Diatoms and dinoflagellates were more sensitive to metals than green algae.

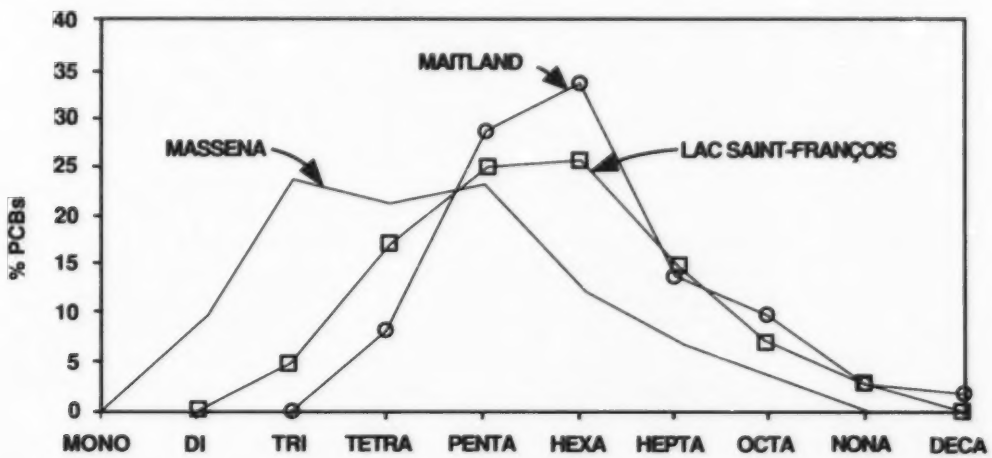


Figure 7. *PCB congener distributions in St. Lawrence River mussels in 1985.*

LONG RANGE TRANSPORT OF AIRBORNE POLLUTANTS PROJECT

D.C.L. Lam, Project Chief

Introduction

The main focus of the Long Range Transport of Airborne Pollutants (LRTAP) Project is the assessment of the aquatic effects of acidic deposition. The research results over the past decade will be summarized in a national assessment report due to be completed in early 1990. Under the project, a large data base has been assembled, including both research and monitoring data on atmospheric deposition, soil characteristics and water chemistry. It provides the information core for the integrative and statistical interpretation of the present status of LRTAP and for the model predictions of possible changes in the aquatic environment under various sulphur emission control scenarios.

Research Highlights

- The LRTAP Project has provided a leadership role on the synthesis of environmental data on sulphur deposition, precipitation, soil sensitivity, lake counts and measures, major chemical ions in streams and lakes, and biological responses, primarily for Eastern Canada where the impacts from acidic deposition are greatest. The data set has been assembled with the collaboration of scientists from Atmospheric Environment Service, Inland Waters Directorate, Canadian Wildlife Service, the Department of Fisheries and Oceans and provincial agencies. These scientists have contributed to the planning and design of the interpretative data presentation (Figure 8). The data, collected from over 10 000 stations, have been made available on microcomputers for interactive graphic display, using an expert system, RAISON (Regional Analysis by Intelligent System ON a microcomputer). This innovative system is used to select the appropriate watershed acidification models for predicting changes in lake conditions in response to possible sulphur emission control scenarios.

- Research has been undertaken to develop a statistically sound basis for making inferences on the number of lakes affected by acidic deposition from a limited data source. Many of the lakes included in the LRTAP data set were not sampled according to randomized design. To avoid possible biases in the assessment process, a new model-based inference method is being developed for non-random samples. Preliminary results using data from Atlantic Canada are encouraging.

- The hydrogeochemical response of the Turkey Lakes Watershed to acidic deposition has been quantified using a mass balance approach. Year-round measurements of surface water fluxes, both hydrological and chemical, have enabled accurate estimations of retention of sulphate ion in the basin. Groundwater data have also provided valuable insights into the hydrological pathways of the major chemical ions, such as calcium and magnesium, which are released from soil minerals in contact with acid. During snowmelt, calcium, sulphate and alkalinity were found to decrease linearly with increasing stream flow, while hydrogen, nitrate and potassium showed increasing concentrations.

- The Turkey Lakes Watershed acidification model has been adapted for application to the Mersey River and Moose Pit Brook in Nova Scotia. A new organic acid submodel has been developed, incorporating a system of mono-, di- and tri-valent forms of organic anions. Different hypotheses on the charge density and activity constants have been tested. The results show that the impact of inorganic acid originating from LRTAP is modulated by the presence of organic acidity. Further, this modulation can vary with the composition of the various organic acid species.

● Detailed field measurements of dissolved organic materials show that hydrophobic acids are the most abundant, humic acids rank second and hydrophilic acids rank third in samples collected from streams and lakes in the Kejimkujik National Park, Nova Scotia. Bioassay results show that, under present conditioning, coloured Nova Scotia waters afford sufficient protection to fish alevins at about 7 mg/L of dissolved organic carbon, and that the hydrophobic acids afford better protection than others. The humic acids can remove metals such as aluminum from the water column, starting at a pH value of 4.5.

● Major presentations on the subject of organic acids and their effects on the water chemistry of streams and lakes were made by scientists of the LRTAP Project at the Kejimkujik Conference '88, an international scientific conference on organic studies. Papers on field studies, statistical data evaluation, simulation modelling and biological impact were delivered and will be published in a special volume of *Water, Air, and Soil Pollution.*

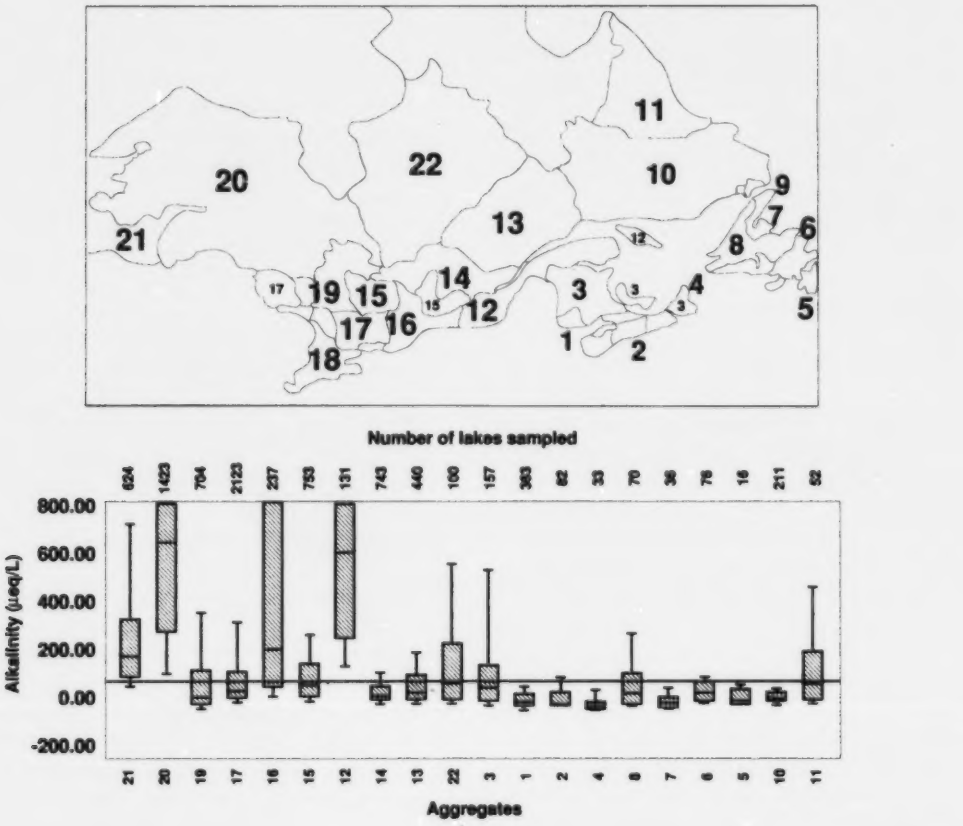


Figure 8. *Observed acid neutralizing capacity (ANC) for 1980-86 data summarized by aggregate for Eastern Canada. Each aggregate is composed of several watersheds grouped according to common soil and water chemistry characteristics. The top and bottom of the box represent the 75th and 25th percentiles and the bar in the box indicates the median. The box is bracketed by the 10th and 90th percentile values. The numbers at the bottom of the boxes are the aggregate numbers and their location is shown on the map. The numbers on top of the boxes indicate the number of lakes included in the analysis within each aggregate.*

ECOTOXICOLOGY PROJECT

B.J. Dutka, Project Chief

Introduction

Ecotoxicological and microbiological tests are important tools for assessing the impact of pollutants on water quality, sediments and biota. These methods permit a determination of the degree and extent of contamination in the environment and the identification of potential ecological impacts. The principal goals of the Ecotoxicology Project are:

- to develop a "battery of tests" protocol for the assessment of contaminant stress in aquatic ecosystems;
- to determine the geographical extent and the local degree of impact;
- to understand contaminant transport in rivers and streams.

The expertise in the Ecotoxicology Project is also used in the provision of scientific advice to national and international governmental agencies and to industry on microbiological problems and on methods for evaluating the ecological significance of toxic contaminants.

Research Highlights

● As part of the "battery of tests" study, different sediment extraction procedures were tested and toxicant screening tests were used on samples from the Yamaska River, Quebec, to evaluate spatial and seasonal variability. Data will be entered into a computerized national data bank. A point allocation and ranking scheme is being developed and will permit comparison and ranking of waters and sediments.

● A new commercial test for mutagenicity/genotoxicity assessment, Mutatox, is being evaluated with the samples from Yamaska River samples. The test measures the ability of a chemical or sample to induce a genetic or epigenetic change in the test organisms. The test is based on the reversal of a dark mutant strain of *Photobacterium* to a light producing strain due to the genetic action of chemicals in the sample being tested. The Ecotoxicology Laboratory is one of two laboratories that are field-evaluating the procedure prior to its marketing.

● The adsorption of contaminants onto suspended matter in aquatic systems is influenced by a variety of parameters, such as particle size distribution, bacterial content, stream velocity, pH, etc. Natural suspended matter from the Yamaska River was used to study the factors controlling the adsorption of contaminants onto particulate matter in aquatic systems. Particles in the 20-40 µm size range were the most abundant and showed the greatest capacity to accumulate contaminant-dye and, therefore, to remove it from water (Figure 9). This same size-fraction also contained the largest microbial populations as determined by the direct microscopic counting procedure and phase-contrast microscope. The results suggest that the 20-40 µm size fraction might play an important role in contaminant transport.

● Two short courses on microbiological and battery-of-tests techniques were organized by the Ecotoxicology Project: a laboratory course was given on toxicant screening procedures to ten participants from Conservation and Protection and the U.S. Geological Survey, and a workshop on microbiological water quality methods was organized at the Bioqual '88 Conference.

● The Academy of Finland requested the participation of the Ecotoxicology Project to provide advice on the ecotoxicology research in Finnish universities, institutes and private laboratories. The results of this review were reported in *Evaluation of Research in Environmental Toxicology in Finland,* Academy of Finland, Helsinki, 1988.

● A member of the Ecotoxicology Project, along with 38 representatives from U.S. government, universities and contractors, participated in a workshop organized by the U.S. EPA in Seattle, Washington, to develop

protocols for the handling of hazardous waste sites in the United States. A major product of the workshop was the U.S. EPA manual *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference.*

● Advice and assistance were given to the Canadian International Development Research Centre (IDRC) concerning a study on the use of simple, inexpensive microbiological tests to assess the quality of raw and potable waters. A five-day workshop was held in Banff, Alberta, with researchers from eight countries involved in the research study and a five-day training session in biological laboratories in St. Lucia was undertaken. Technology transfer from these international studies includes a joint project, in collaboration with Inland Waters Directorate (Western and Northern Region) and National Health and Welfare, to transfer the IDRC proposed procedures to the Split Lake Native Band in northern Manitoba.

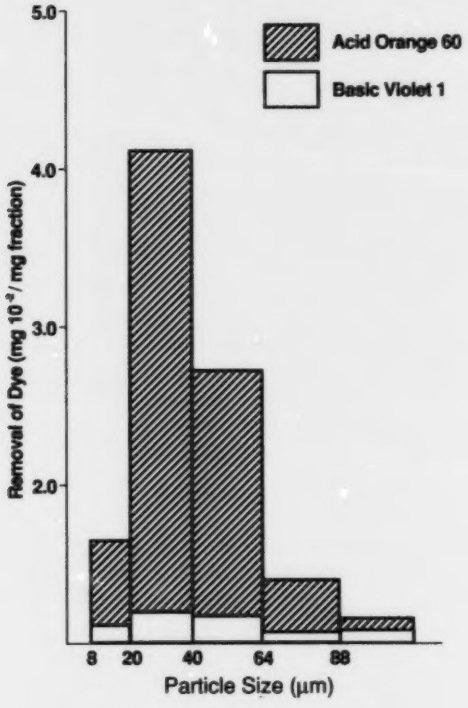


Figure 9. *Removal of contaminant-dye from the water by different particle-size fraction in suspended matter. Results are expressed as mg of dye removed from water by mg of dry weight of particles.*

GROUNDWATER CONTAMINATION PROJECT

R.E. Jackson, Project Chief

Introduction

Research in the Groundwater Contamination Project is focused on the migration and fate of toxic contaminants in groundwater using instrumented field sites, laboratory experiments and mathematical models developed at NWRI and, through a cooperative agreement, at the University of New Brunswick. The three main objectives of the project are:

- to understand the physical and chemical controls on contaminant migration and fate in sedimentary rock aquifers, such as liquid industrial wastes in the limestones of the Niagara region, and liquid industrial wastes in the sandstones underlying Prince Edward Island (P.E.I.);
- to develop and/or apply operational tools for hazardous waste site assessment and restoration of outwash aquifers;
- to provide expert advice on groundwater pollution matters of federal concern in Eastern Canada.

Research Highlights

● About 164 hazardous waste sites have been identified within five kilometres of the Niagara River on the U.S. side of the frontier. Seepage from these sites threatens the quality of both the Niagara River and Lake Ontario. During the summer of 1988, NWRI scientists carried out detailed hydraulic tests in three boreholes drilled by the U.S. Geological Survey (USGS) in the city of Niagara Falls, N.Y. Individual horizontal fractures, the most significant potential pathways for contaminant migration, were identified and characterized in the uppermost bedrock formations. Four or five fractures, which may be of considerable lateral extent, predominate the groundwater flow regime. Results are to be incorporated into a three-dimensional numerical model of groundwater flow in the Niagara Region, currently under development by the USGS.

● NWRI scientists are working with engineers from the Wastewater Technology Centre and various consulting firms to appraise groundwater contamination at several hazardous waste sites at which federal funds are being spent to restore aquifers or to assess cleanup options. A review of past studies emphasizes that inadequate hydrogeological and chemical investigations of a site at the outset may lead to the selection of inappropriate remedial technologies. This, in turn, can result in inefficient decontamination.

● A field site at Petro-Canada's Clarkson refinery has been developed jointly by the Waterloo Centre for Groundwater Research and NWRI. The site is being used to assess the importance of fracture apertures, spacings and orientations on the hydraulic properties of sedimentary rocks. This information is important in the Great Lakes region because of the intimate relationship between bedrock fractures and the migration of toxic chemicals from hazardous waste sites. Laboratory simulations of identified fractures suggest that slight variations in mean aperture width lead to substantial channelling of contaminants in fractured rock, thereby making the task of predicting contaminant transport in fractured rock very difficult.

● The pulse interference test method, which is employed to determine the transmissivity and storage capacity of a geological formation between two wells, is an attractive alternative to the more commonly used pumping test method. The results of a field comparison, in which pulse interference and pumping tests were conducted between two wells, indicate that the new pulse interference test method is as accurate as the pumping-test method but less time-consuming to conduct and analyze.

● A graphical technique has been developed to discriminate between the sources of aromatic hydrocarbons in groundwater.

These compounds, known as BTEX (benzene, toluene, ethyl benzene and xylene), may come from natural hydrocarbon sources, such as oil and natural gas, or alternatively from refined products, such as gasoline. The use of this technique to study groundwaters from a deep borehole in Sarnia, Ontario, has shown that it is possible to differentiate zones containing BTEX from natural petroleum deposits and zones containing disposed industrial waste liquids (Figure 10).

● Detailed chemical analysis of goundwaters contaminated with organic solvent residues at the Gloucester Landfill, near Ottawa, have shown the presence of several freon products. The parent compound is F113, a solvent used in chemical analysis and in microelectronic manufacturing. It is associated with several very large plumes of contaminated groundwater in the United States. NWRI scientists have discovered that this seemingly stable compound, associated with ozone degradation in the upper atmosphere, is in fact unstable in anoxic groundwater and breaks down by reductive dehalogenation and elimination reactions. While F113 is quite harmless, there is concern that the degradation products are not, in particular F1113, an analog of the human carcinogen vinyl chloride.

● Continued monitoring of pesticide contamination of the sandstone aquifer of P.E.I. has shown that aldicarb is extremely persistent in the acid soils beneath the potato fields on which it is used. In May 1988, detailed monitoring over the course of one month showed that 10 percent of all monitoring wells had aldicarb concentrations in excess of National Health and Welfare's drinking water guideline of 9 ppb. At the same time, however, 50 percent had nitrate concentrations in excess of the 10 ppm guideline. This may suggest that nitrate levels in the groundwater beneath agricultural areas in the Maritimes represent a greater concern than aldicarb contamination.

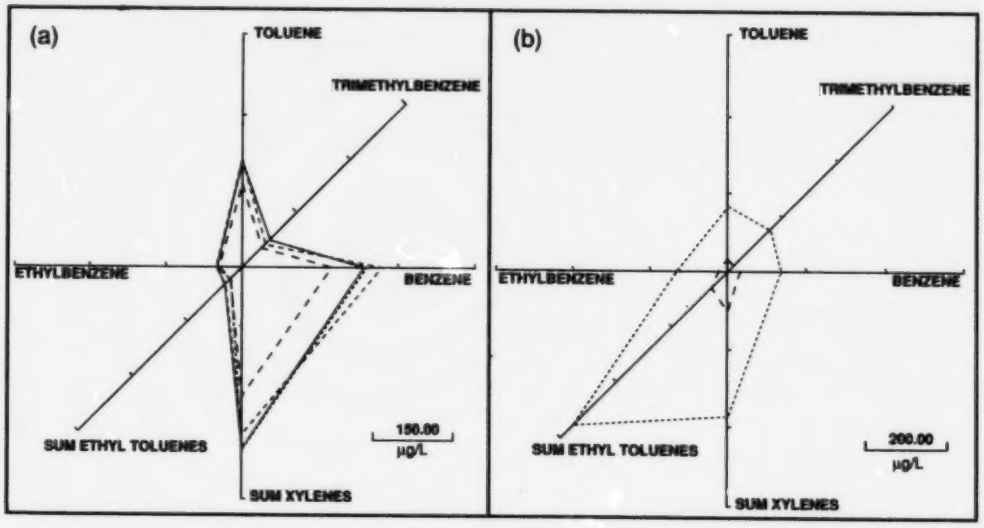
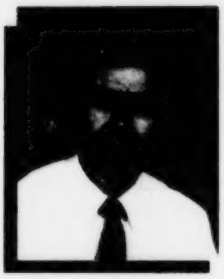


Figure 10. *(a): BTEX residues in groundwater from natural petroleum deposits. (b): BTEX residues in groundwater from industrial waste disposal zones.*

RESEARCH AND APPLICATIONS BRANCH

J. Lawrence, Director



The Research and Applications Branch conducts mission-oriented basic and applied research in areas of analytical chemistry and hydraulics. It is also responsible for transferring research and technology to the operational sectors of Environment Canada and for providing technical and scientific services, such as current meter calibration, sedimentology and geotechnical services, and analytical quality assurance. The Branch also has corporate responsibility for third party, cost-recovery work with universities and the private sector.

The activities of the Branch are organized into three projects: **Analytical Chemistry**; **Hydraulics**; and **Quality Assurance**.

New, improved and more cost-effective analytical techniques (including laboratory automation) are developed and evaluated for the measurement of priority chemical and biochemical parameters in environmental samples. The Branch also has lead responsibility for analytical quality assurance for most of Conservation and Protection's chemical monitoring programs. Support is provided primarily to: NWRI, the national and regional laboratories of Conservation and Protection, the ferleral-provincial water quality agreements, the LRTAP program, the Prairie Provinces Water Board (PPWB) and the Great Lakes Water Quality Agreement.

Knowledge of the dynamics of water is sought to provide a framework for the management of water resources and for biology and chemistry research in the aquatic environment. The interfaces between water and the atmosphere, bottom sediments, and shore are studied to explain the mechanisms controlling the transport of pollutants and erosion. Advances are made in river metrology to improve management of that resource. The major clients are the Water Resources Branch, Water Planning and Management Branch, Great Lakes Environment Office, Environmental Protection, and the Atmospheric Environment Service.

Universities and private industry are encouraged to make use of the facilities and expertise of the Branch either by collaborative studies with the professional staff or by leasing of the facility, with or without technical support. The Branch maintains a well-equipped hydraulics laboratory, sedimentology and geotechnical laboratories, and a "Special Clean and Hazardous Chemical Laboratory," in addition to conventional chemical laboratories. All direct requests from external agencies are cost-recovered, in full or in part, in accordance with the federal policy.

ANALYTICAL CHEMISTRY PROJECT

I. Sekerka, Project Chief

Introduction

The continuing goal of the Analytical Chemistry Project is to advance knowledge and provide expertise on environmental analytical chemistry. New analytical protocols, instrumentation and methods are essential for the assessment and management of water resources and for water pollution research, especially the identification of emerging problems. The objectives of the project are:

- to develop new and improved analytical methods, as well as screening and sampling procedures, which are accurate, cost-effective, sensitive and unambiguous, for the identification and quantification of contaminants in aquatic ecosystems;
- to play a lead role in documentation, validation and standardization of analytical methodologies to ensure accuracy and reliability of analytical data;
- to provide NWRI with sophisticated instrumentation and facilities, such as gas chromatography/mass spectrometry (GC/MS) and the "Special Clean and Hazardous Chemical Laboratory;"
- to transfer developed methods and technologies to the national and regional laboratories of IWD and a wide variety of other "users".

Research Highlights

● Recently, there has been a great deal of concern about the environmental impact of the pollution created by the bleaching of pulp. Numerous chlorinated phenolics are discharged into rivers and lakes by the pulp and paper industry. In order to monitor these compounds, a simple, but comprehensive, analytical method for the determination of all major chlorinated phenolics in pulp and paper mill effluents has been developed jointly by the Research and Applications Branch and the Wastewater Technology Centre. The performance of the "Goulden large sample extractor" has also been validated for the preconcentration of pulp and paper effluents.

● Boron is often used in the characterization and monitoring of water quality. Small amounts (µg/L) are present in most natural waters, and increasing amounts are introduced by industrial and domestic wastes. Boron in the form of borate is an important component of aqueous acid and base neutralizing capacity, an important parameter for acid rain studies and management. A flow injection method for boron has been developed at the request of the National Water Quality Laboratory (NWQL). It meets all requirements of automation, sensitivity and reproducibility.

● Acid-neutralizing capacity of water is a parameter of great importance for studies of aquatic ecosystems. An automated conductometric acid-base titration method has been developed for the determination of acid-neutralizing capacity. Performance was evaluated and compared with performance of potentiometric titration. Conductometric titration is simple, fast, sensitive (detection limit 0.1 ppm) and accurate. Relative standard deviations of the determination increased from about 1 percent at high levels to about 10 percent at the 0.1 ppm level. The system is equipped with a "desktop" computer to handle data and to control the sample changer, autoburette and conductivity meter.

● Broad-spectrum analysis is a newly introduced concept for the classification and grouping of pollutants in environmental samples. The goal is to develop methodologies capable of recognizing and registering all components of a sample. The development and application of a congener-specific method using dual column gas chromatography, together with automated data han-

dling and interpretation programs, resulted in more objective results and a higher degree of confidence.

● An ion chromatographic method for simultaneous analysis of major organic and inorganic acids (formic, acetic, nitric, sulphuric, hydrochloric and hydrofluoric) in precipitation samples has been developed. The method can also determine several other acids commonly present in precipitation-related samples, namely, propionic, glycolic, butyric, methanesulfonic, nitrous, hydroxymethylsulfonic, oxalic, phosphoric and citric acids. The method is being adapted for routine analysis of these acids by the NWQL.

● Supercritical fluid extraction (SFE) is a time-saving technique used for efficient extraction of contaminants from various environmental samples. Two types of SFE have been designed—the dynamic leaching process is simpler, but the steady-state type is more economical. Both systems were interfaced to the capillary column chromatograph for further research of supercritical fluid chromatography (Figure 11).

● Extensive tests of the robotic flow injection analysis-inductively coupled plasma atomic spectroscopy (FIA-ICAP) system under the conditions of routine daily operation in the NWQL provided very good reproducibility, reliability and time effectiveness.

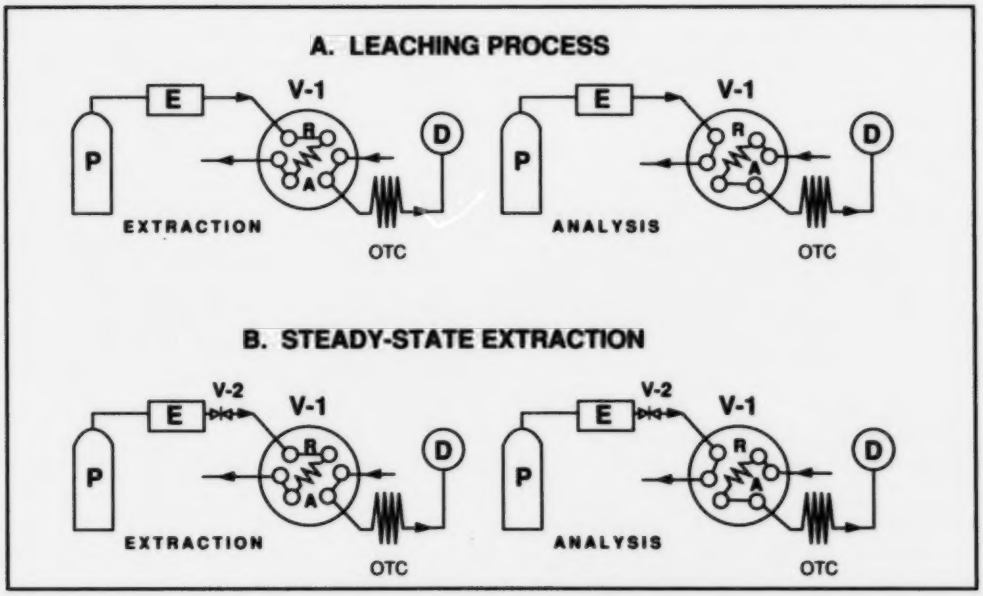


Figure 11. *Schematics of the leaching (A) and steady-state extraction (B) illustrating supercritical fluid extraction-high resolution gas chromatography (SFE-HRGC) interfacing technique. P, high pressure pump; E, extraction vessel; V1, 6-way switching valve; V-2, on/off valve; A, accumulator; D, detector; OTC, open tubular column; R, restrictor.*

HYDRAULICS PROJECT

M. Skafel, Project Chief

Introduction

Research in the Hydraulics Project focuses on the physical dynamics of water and its interaction with air, sediments, shores and man-made structures. Studies on wave mechanics, river flow and sediment transport provide new knowledge for use by water resource managers and engineers in Environment Canada and elsewhere. Special attention is given to understanding hydraulic processes that could lead to structural failure with serious environmental consequences.

Wave mechanics studies create new knowledge to advance the understanding of toxic gas transfer, diffusion of pollutants, wave prediction, lake circulation, seasonal thermocline development, weather forecasting and climatic change. Coastal engineering studies address lake bottom interactions to understand sediment resuspension, shoreline evolution and wave-structure interaction. Fluvial engineering research is directed at improved understanding of fluid mechanics and sediment transport in rivers, the development of new and improved techniques for monitoring river processes, and flow-structure interactions.

Research Highlights

- As a result of a research suggestion from representatives of the Canadian oil industry, physical hydraulic model tests of a pipeline in a trench, typical of Beaufort Sea designs, were conducted in the wind-wave flume. Environmental conditions in the Beaufort Sea necessitate pipeline trenching to avoid bottom scour by ice, yet existing pipeline design information deals almost exclusively with flat beds. Wave-induced forces on a pipe in a trench were measured and are being compared with existing design information for pipes on a flat bed.

- The variation of water levels in the Great Lakes has been examined using historical and archaeological evidence from the early 17th century and later, as well as using water level simulation results from a numerical hydrologic response model. Findings indicate that, over at least the last 400 years, climate-related variations in maximum mean annual lake levels have probably not been exceeded since recorded measurements began in the early 19th century. This stands in contrast to previous scientific studies reporting episodic changes of 1 m to 2 m in mean Great Lakes levels, lasting two to three centuries, as a result of climate change over the last 3000 years.

- As part of an inter-departmental technical review committee, advice was provided on long-term shore management alternatives to reduce beach erosion and the risk of flooding north of Point Pelee National Park, Ontario. Shore processes and shore protection methods were examined at this site. The recommended long-term solution is a non-structural alternative to convert part of the drained agricultural land north of the park back to a wetland environment.

- Construction of an air-tight gas transfer flume for determining mass transfer coefficients of organic chemicals, as well as parameters related to wave mechanics and boundary layer turbulence, has been completed. Preliminary testing and evaluation of the performance of this unique facility is currently under way, in collaboration with the Air-Water Interactions Project. Although the exchange of organic contaminants across the air-water interface has been recognized as an important process influencing the fate of these chemicals, the magnitude and even the direction of this transfer cannot yet be modelled reliably. A better understanding of the factors controlling the mass transfer of toxic chemicals at the air-water interface is essential for the accurate modelling of the movement and ultimate fate of these chemicals in the environment.

● The final weir design for the Milk River at Eastern Crossing, Montana, USA, was selected and a series of tests to determine the erodibility of the sand bed immediately upstream of the river were completed. The Milk River is a sand-bed stream with an unstable stage-discharge relationship caused by shifting channel bed and migrating sand waves. The new weir design should provide accurate discharge records so that the apportionment of water between Canada and the USA, as dictated by the Boundary Waters Treaty, can be satisfied. The work is being conducted for the Water Resources Branch, Inland Waters Directorate, in Western and Northern Region.

● Extensive tests were conducted in a large physical model of the re-designed Windermere Basin (Figure 12), the enclosed body of water at the south end of Hamilton Harbour. Several schemes for flow conditioning were evaluated, including spur dikes, a weir at the outflow, a flow deflector at the entrance of the basin and a sediment trap. The aim of the study was to find the most effective way to minimize the transport of suspended sediments from Red Hill Creek and other sources into the open harbour.

● Cost-recovery studies were conducted in the hydraulics laboratory for several external clients. These included a hydraulic model of a non-standard Parshall flume for flow measurement in a trunk sewer (Regional Municipality of York); a hydraulic model to determine the design wave conditions for, and stability of, a rubble mound breakwater (Sandwell Swan Wooster Inc.); special calibration tests in the towing tank of various current meters (Bedford Institute of Oceanography, Ontario Ministry of the Environment, Ontario Hydro); qualitative hydraulic model tests of trench infilling rates due to waves and currents over a sandy bed (Atria Engineering Hydraulics Inc.); and rental of the coastal research tower in Lake Ontario for radar transmission tests (Defense Research Establishment, Ottawa).

Figure 12. *Windermere Basin model.*

QUALITY ASSURANCE PROJECT

A.S.Y. Chau, Project Chief

Introduction

The objectives of the Quality Assurance Project are to provide a focal point for coordinated quality assurance (QA) programs in Environment Canada and to ensure that analytical data are generally of good and comparable quality. Assurance of data quality enables the Department to provide authoritative and credible scientific advice on control and remediation strategies derived from the interpretation of scientific data.

Chemical data are essential for decisions on aquatic pollution control. Biased measurements can lead to errors in assessment and in subsequent control actions. In addition, the expense of data collection and interpretation makes the cost of discarding questionable data high. Therefore, data must be suitable, compatible and reliable for the intended use. The long-term goal of the Quality Assurance Project is to assist with the development of comprehensive analytical QA programs in Canada.

The Quality Assurance Project plans, coordinates and implements quality assurance and quality control (QA/QC) programs. It also develops Certified Reference Materials (CRMs)—water, sediments and biota—for use in quality assurance, analytical method development and environmental assessment studies (Table 1).

Project activities include:

- the development of management plans for quality assurance;
- advising on field, laboratory and data management quality control procedures;
- the development of CRMs;
- the design and conduct of interlaboratory comparison studies.

Studies are conducted for federal, provincial, university and private laboratories producing analytical data for departmental programs. Methodology evaluation and sample preservation are also carried out in support of these studies.

An active program to market the products and expertise of the project has begun. The first step has been to advertise the availability of the CRMs developed and prepared by the group.

Research Highlights

- In response to Saint-Basile-le-Grand fire emergency, a special interlaboratory study was designed and conducted to assess data comparability. At the urgent request of Environment Protection, detailed consultation and advice were also provided on QA/QC for the B.C. Mill emergency dioxin analyses. A multi-agency and federal-industry QA Committee was formed to provide QA and data evaluation for the national monitoring of dioxin in pulp and paper.

- Special sediment reference samples for dioxin were prepared with assistance from the Analytical Chemistry Project, and a reference water sample (200 bottles) for dioxin was prepared for interlaboratory QA studies. This is a pilot study for the future development of a large-volume sample as CRM for dioxin.

- A continuing study to verify the stability of CRMs shows that no detectable degradation was observed for polychlorinated biphenyls (PCBs), chlorinated biphenyls (CBs) and polynuclear aromatic hydrocarbons (PAHs) after two years of storage at 0° C.

● Activities continued for three national QA programs for inorganic parameters: The Federal/Provincial Agreement QA program, the Prairie Provinces Water Board QA program, and the Long Range Transport of Airborne Pollutants (LRTAP) program. In addition, the Prairie Provinces Water Board received a large, integrated report on laboratory performance for the year. For the LRTAP program, three large QA studies for major ions and nutrients were designed and conducted. Computer programs were also developed to provide information on laboratory performance and data quality.

Toxic Organics

CRM/RM Identification	Sediment Source	Year Initiated	Parameters†
EC-1	Hamilton Harbour	1978	PCB , PAH
EC-2	Lake Ontario	1980	PCB*, PAH*, chlorobenzenes
EC-3	Niagara River Plume	1982	PCB*, PAH*, chlorobenzenes*
EC-4	Toronto Harbour	1983	PCB*, PAH*
EC-5	Humber River	1983	PCB*, PAH*
EC-6	Lake Erie	1986	PCB*, PAH*
EC-7	Lake St. Clair	1987	PCB*, PAH*

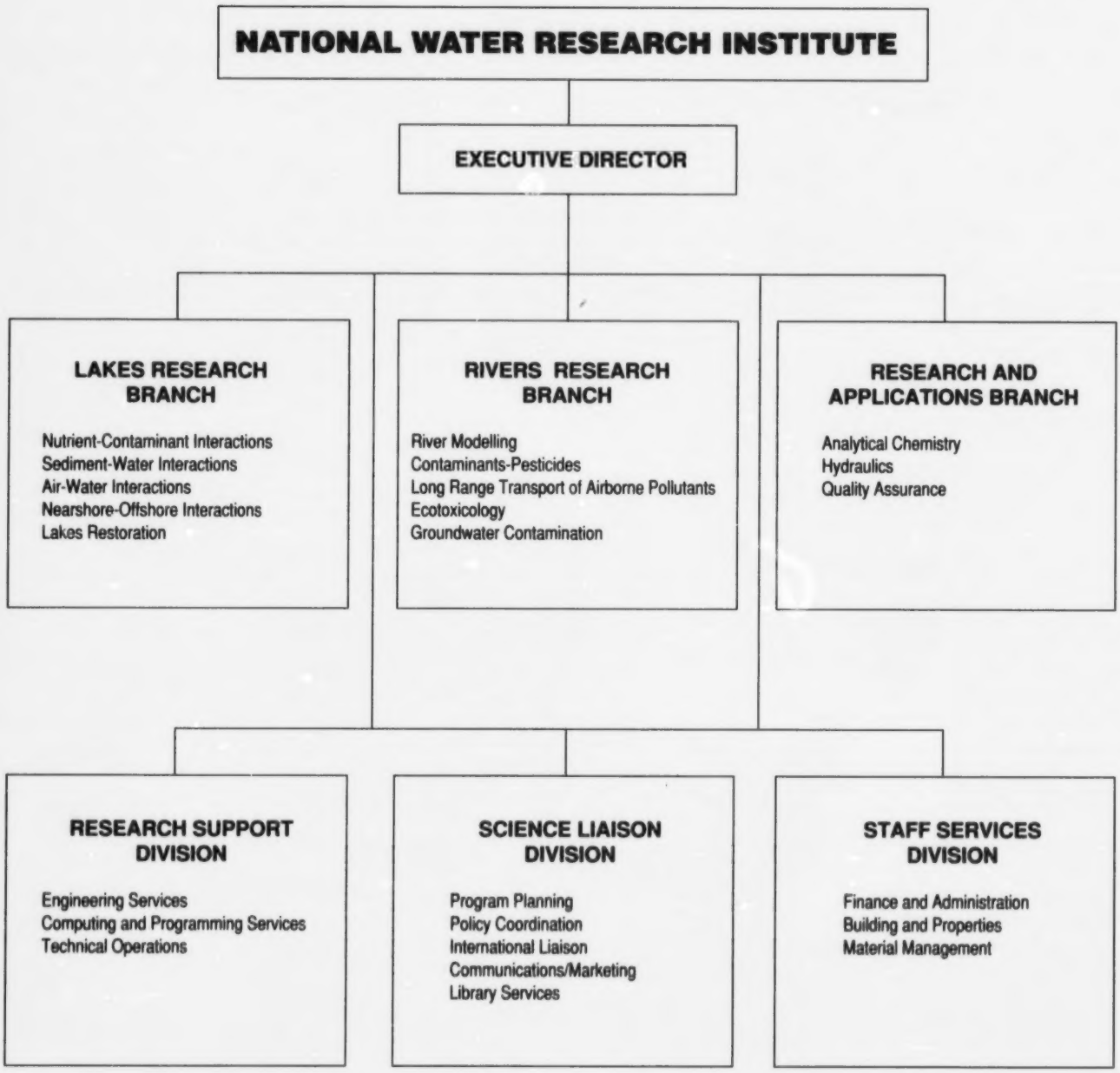
Inorganics

CRM/RM Identification	Sediment Source	Year Initiated	Parameters	Concentration Range (µg/g)
WQB-1	Lake Ontario	1974	As, Se, Hg	1-23
WQB-2	Lake Ontario	1974	As, Se, Hg, Trace metals*	1-280
WQB-3	Hamilton Harbour	1980	As, Se, Hg, Trace metals	4-1400
SUD-1	Sudbury	1982	Trace metals*	2-950
TH-1	Toronto Harbour	1983	Trace metals*	5-1500
HR-1	Humber River	1983	Trace metals*	4-1100

Table 1. *Certified Reference Materials (CRMs) and Reference Materials (RMs) developed by the Quality Assurance Project for the analysis of toxic organics and inorganics in sediments.*

† Concentration levels of organic parameters range from 0.01 to 25.0 µg/g and vary between the different CRMs and RMs.

* Certification in progress for some parameters.


NATIONAL WATER RESEARCH INSTITUTE
EXECUTIVE DIRECTOR
LAKES RESEARCH BRANCH
Nutrient-Contaminant Interactions
Sediment-Water Interactions
Air-Water Interactions
Nearshore-Offshore Interactions
Lakes Restoration
RIVERS RESEARCH BRANCH
River Modelling
Contaminants-Pesticides
Long Range Transport of Airborne Pollutants
Ecotoxicology
Groundwater Contamination
RESEARCH AND APPLICATIONS BRANCH
Analytical Chemistry
Hydraulics
Quality Assurance
RESEARCH SUPPORT DIVISION
Engineering Services
Computing and Programming Services
Technical Operations
SCIENCE LIAISON DIVISION
Program Planning
Policy Coordination
International Liaison
Communications/Marketing
Library Services
STAFF SERVICES DIVISION
Finance and Administration
Building and Properties
Material Management

PUBLICATIONS AND SCIENTIFIC STAFF

NWRI MANAGEMENT TEAM

Executive Director
D.L. Egar
B. Eng. (Carleton), M.A.Sc. (Ottawa)
hydraulics and water resources engineering

Director, Lakes Research Branch
Dr. R.J. Allan
B.Sc. (Aberdeen), M.S. (Wisconsin), Ph.D. (Dartmouth), D.Sc. (Aberdeen)
applied geochemistry and limnology

Director, Rivers Research Branch
Dr. E.D. Ongley
B.A. (Toronto), Ph.D. (Sydney)
geomorphology and land-water interactions

Director, Research and Applications Branch
Dr. J. Lawrence
B.Sc., Ph.D. (Bristol)
analytical chemistry and quality assurance

Chief, Science Liaison Division
Dr. R.J. Daley
B.A., M.Sc., Ph.D. (Queen's)
limnology and microbial ecology

Chief, Research Support Division
J.D. Smith, C.D.

A/Chief, Staff Services Division
J. Jagoe

LAKES RESEARCH BRANCH

Director's Office

Director
Dr. R.J. Allan
B.Sc. (Aberdeen), M.S. (Wisconsin), Ph.D. (Dartmouth), D.Sc. (Aberdeen)
applied geochemistry and limnology

Senior Limnologist
Dr. J.M. Barica
B.Sc., M.Sc. (Bratislava), Ph.D.,D.Sc. (Prague)
limnology and algal ecology

Science Liaison Coordinator
C.B. Gray
B.Sc. (British Columbia), M.Sc. (Queen's)
biogeochemical limnology and lake restoration

PUBLICATIONS

Allan, R.J. (ed.). 1988. Book of Abstracts: International Symposium on the Fate and Effects of Toxic Chemicals in Large Rivers and Estuaries. 116 p.

Allan, R.J. 1988. Toxic organic chemical pollution of lakes, with emphasis on the Laurentian Great Lakes aquatic ecosystem. Symp. Biol. Hung. 38, Akademiai Kiado, Budapest, p. 217-243.

Allan, R.J. 1989. An overview of pollution of the Fraser River estuary by chlorinated phenolic compounds. NWRI Contribution 89-30.

Allan, R.J. 1989. Mining activities as sources of metals and metalloids to the hydrosphere. p. 45-67. *In* Proceedings of the Workshop on Metals and Metalloids in the Hydrosphere, Impact Through Mining and Industry, and Prevention Technology. Technical Documents in Hydrology, UNESCO Press, Paris.

Barica, J. 1988. Cyclic instabilities in hypereutrophic lakes. Czech translation of D.Sc. dissertation synopsis. Charles University, Prague. 68 p.

Barica, J. 1988. Recovery of the Laurentian Great Lakes, 1970-1985: eutrophication aspects. NWRI Contribution 88-44.

Barica, J. and **R.J. Allan**. 1988. Utility of SRP measurements in Great Lakes surveillance programs: a summary. J. Great Lakes Res. 14: 377-379.

Barica, J., D.J. Poulton, B. Kohli and M.N. Charlton. 1988. Water exchange between Lake Ontario and Hamilton Harbour: water quality implications. Water Poll. Res. J. Canada 23: 213-226.

Barica, J. and C. Vieira. 1988. Nitrogen, phosphorus and chlorophyll *a* regime of Hamilton Harbour. NWRI Contribution 88-43.

Barica, J. 1989. Unique limnological phenomena affecting water quality of Hamilton Harbour, Lake Ontario. J. Great Lakes Res. In press.

Gray, C.B. and D. Rathke. 1988. Remedial Action Plan Research Needs. Report to the Council of Great Lakes Research Managers, International Joint Commission, Windsor, Ontario. 33 p.

Mudroch, A., **R.J. Allan** and S.R. Joshi. 1989. Toxic chemicals in sediments of Great Slave Lake, Northwest Territories, Canada. NWRI Contribution 89-21.

Nutrient-Contaminant Interactions

Project Chief
Dr. J.H. Carey
B.Sc., M.Sc. (Windsor), Ph.D. (Carleton)
pathways of organic contaminants in aquatic ecosystems

Study Leaders
Dr. R.M. Baxter
B.Sc. (Mount Allison), Ph.D. (McGill)
reductive dehalogenation of contaminants and impacts of reservoirs

F.M. Boyce
B.A.Sc. (British Columbia), M.Sc. (McGill)
physical limnology

Dr. B.K. Burnison
B.S. (Montana), M.S., Ph.D. (Oregon State)
effects of contaminants on microbial activity

F. Chiocchio
B. Eng. (Waterloo)
physical limnology

Dr. S.R. Esterby
B.A. (Queen's), Ph.D. (Waterloo)
applied environmental statistics

Dr. D.R.S. Lean
B.A.Sc., Ph.D. (Toronto)
bioenergenetics in lake ecosystems

Dr. G.G. Leppard
B.A., B.Sc., M.A. (Saskatchewan), M.S., M.Phil., Ph.D. (Yale)
cell physiology

Professional and Technical Staff
K. Edmondson, B.Sc. (Western Ontario); J.H. Hart; D.J. Nuttley

PUBLICATIONS

Boyce, F.M., M.A. Donelan, P.F. Hamblin, C.R. Murthy and J.T. Simons. 1988. Thermal structure and circulation in the Great Lakes. Atmosphere-Ocean. In press.

Boyce, F.M., P.F. Hamblin, **F. Chiocchio** and D.G. Robertson. 1989. Evaluation of sediment traps in Lake St. Clair, Lake Ontario and in Hamilton Harbour. NWRI Contribution 89-09.

Boyce, F.M., W.M. Schertzer, P.F. Hamblin and R. Murthy. 1989. An assessment of current understanding of the physical behaviour of Lake Ontario with reference to contaminant pathways and climate change. NWRI Contribution 89-23.

Buffle, J., R.R. DeVitre, D. Perret and **G.G. Leppard**. 1988. Physico-chemical characteristics of a colloidal iron phosphate species formed at the toxic-anoxic interface of a eutrophic lake. Geochim. Cosmochim. Acta. In press.

Carey, J.H., M.E. Fox and **J.H. Hart**. 1988. Identity and distribution of chlorophenols by early life stages of Fraser River pink and Chinook salmon *(Oncorhynchus gorbuscha, O. tshawytscha)*. Water Poll. Res. J. Canada 23: 88-99.

Carey, J.H., M.E. Fox and L.P. Schleen. 1988. Photodegradation of the lampricide 3-trifluoromethyl-4-nitrophenol (TFM). 2. Field confirmation of direct photolysis and persistence of formulation impurities in a stream during treatment. J. Great Lakes Res. 14: 338-346.

Carey, J.H. and **J.H. Hart**. 1988. Sources of chlorophenolic compounds to the Fraser River estuary. Water Poll Res. J. Canada 23: 55-68.

Carey, J.H. and C.R. Murthy [eds.]. 1988. Water pollution related research in the lower Fraser River, British Columbia. Special issue of the Water Poll. Res. J. Canada 23(1): 212 p.

Cooper, W.J., **D.R.S. Lean** and **J.H. Carey**. 1989. Spatial and temporal patterns of hydrogen peroxide in lakes. Can. J. Fish. Aquat. Sci. In press.

Esterby, S.R., A.H. El-Shaarawi, G.D. Howell and T.A. Clair. 1988. Detailed results of the stratification of sets of Nova Scotia and Newfoundland lakes. NWRI Contribution 89-24.

Fox, M.E. and **J.H. Carey**. 1989. Dynamics of plume dispersion of 1,2,3,4-tetrachlorobenzene from the Niagara River into Lake Ontario. NWRI Contribution 89-52.

Hamblin, P.F., J.A. Bull and **F. Chiocchio**. 1989. A note on a microprocessor-based recording current meter suitable for wave research. NWRI Contribution 89-54.

Lam, D.C.L., R.C. McCrimmon, **J.H. Carey** and C.R. Murthy. 1988. Modelling the transport and pathways of tetrachlorophenol in the Fraser River. Water Poll. Res. J. Canada 23: 141-159.

Lean, D.R.S., F.R. Pick, S.F. Mitchell, M.T. Downes, P.T. Woods and E. White. 1989. Lake Okaro enclosure experiments: test ecosystems to evaluate plankton phosphorus and nitrogen deficiency. Hydrobiol. Bein. Limnol. In press.

Leppard, G.G., J. Buffle, R.R. DeVitre and D. Perret. 1988. Colloidal iron oxyhydroxyphosphate: the sizing and morphology of an amorphous species in relation to partitioning phenomena. Sci. Tot. Env. In press.

Maguire, R.J., **J.H. Carey**, M.E. Fox, B.G. Brownlee and H.B. Lee. 1988. Assessment of the environmental dynamics of selected pesticides of importance in Western Canada. NWRI Contribution 88-20.

Maguire, R.J., **J.H. Carey**, **J.H. Hart**, R.J. Tkacz and H.B. Lee. 1989. Persistence and fate of deltamethrin sprayed in a pond. J. Agric. Food Chem. In press.

Mazumder, A., D.J. McQueen, W.D. Taylor and **D.R.S. Lean**. 1989. Impact of micro- and meso-zooplankton grazers in contrasting plankton communities produced by planktivore manipulation and fertilization. Limnol. Oceanogr. In press.

Mazumder, A., W.D. Taylor, D.J. McQueen and **D.R.S. Lean**. 1989. Effects of fertilization and planktivorous fish predation on epilimnetic total phosphorus and phosphorus sedimentation: large lake enclosure experiments. Can. J. Fish. Aquat. Sci. In press.

McQueen, D.J., M.R.S. Johannes, J.R. Post, T.J. Stewart and **D.R.S. Lean**. 1989. Field testing the biomanipulation and cascading trophic interaction models. Ecological Monographs. In press.

Metcalfe, J.L., M.E. Fox and **J.E. Carey**. 1988. Freshwater leeches as a screening tool for detecting contaminants in the environment. Environ. Monit. Assess. 11: 147-169.

Nagy, E., **J.H. Carey** and **J.H. Hart**. 1989. Hydrocarbons in Great Lakes sediments. NWRI Contribution 89-01.

Nagy, E., **J.H. Carey** and E.D. Ongley. 1989. Under-ice hydrocarbons in the Mackenzie River. NWRI Contribution 89-10.

Oliver, B.G., **R.M. Baxter** and H.B. Lee. 1989. Polychlorinated biphenyls. p. 31-68. *In* B.K. Afghan and A.S.Y. Chau [eds.] Analysis of Trace Organics in the Aquatic Environment. CRC Press Inc., Boca Raton, Fla.

Sediment-Water Interactions

Project Chief

A. Mudroch
Dipl. Chem. (State College, Prague), M.Sc. (McMaster)
bioavailability of sediment contaminants

Study Leaders

Dr. J.P. Coakley
B.Sc. (St. Francis Xavier), M.Sc. (Ottawa), Ph.D. (Waterloo)
nearshore processes and sediment dynamics

Dr. S.R. Joshi
B.Sc. (Punjab), M.Sc., Ph.D. (Roorkee)
aquatic pathways of radionuclides

Dr. E. Nagy
Dipl. Chem. (Debrecen), M.Sc., Ph.D. (Saskatchewan)
accumulation and persistence of organic contaminants in freshwater sediments

Dr. T. Reynoldson
B.Sc. (Leeds), M.Sc. (Calgary), Ph.D. (Lancaster)
benthic invertebrates and sediment contaminant cycling

F. Rosa
B.Sc. (McMaster)
sediment-water processes and contaminant cycling

A.J. Zeman
B.Sc. (Queen's), M.Sc. (McGill)
subaqueous erosion of lacustrine sediments

Professional and Technical Staff

J.A. FitzGerald; S.P. Thompson, B.Sc. (Guelph)

PUBLICATIONS

Bishop, C.T. and **J.P. Coakley**. 1989. Discussion of: Stratigraphy of the Sixteen Mile Creek Lagoon and its Implications for Lake Ontario Water Levels by J.E. Flint, R.W. Dalrymple and J.J. Flint. Can. J. Earth Sci. In press.

Bobba, A.G. and **S.R. Joshi**. 1988. Groundwater transport of radium-226 and uranium from Port Granby waste management site to Lake Ontario. Nucl. Chem. Waste Manage. 8: 199-209

Coakley, J.P. 1988. The origin and evolution of a complex cuspate foreland: Pointe-aux-Pins, Lake Erie. Géographie Physique et Quaternaire. In press.

Coakley, J.P. and B.F.N. Long. 1988. Tracing the movement of fine-grained sediment in aquatic systems: a literature review. NWRI Contribution 88-23.

Coakley, J.P., M.G. Skafel, R.G.D. Davidson-Arnott, **A.J. Zeman** and N.A. Rukavina. 1988. Computer simulation of nearshore profile evolution in cohesive materials. NWRI Contribution 88-25.

Coakley, J.P., J.C. Dionne and D. Brodeur. 1989. Literature review and bibliography of the geological processes and bottom sediments of the St. Lawrence River. NWRI Contribution 89-07.

Coakley, J.P. and N.A. Rukavina. 1989. Nearshore bedload and suspended sediment transport in the vicinity of Pickering Nuclear Generating Station, Lake Ontario. NWRI Contribution 89-17.

Joshi, S.R. and A.G. Bobba. 1988. Finite element modelling of transport Ra-226 and U from a radioactive waste management site to Lake Ontario. p. 193-200. *In* G. Desmet [ed.] Reliability of Radioactive Transfer Models. Elsevier Science Publishers.

Mudroch, A. 1988. Distribution of mercury in Lake St. Clair and the St. Clair River sediments. Amer. Chemical Soc., Div. Environ. Chem., Extended Abstracts, p. 289-290.

Mudroch, A. and **S.R. Joshi**. 1988. Geochemistry and distribution of metals in radiodated sediment cores from Lake Saint-Louis, St. Lawrence River. NWRI Contribution 88-31.

Mudroch, A. 1989. Treatment of contaminated sediments. *In* Options for the Remediation of Contaminated Sediments in the Great Lakes. Report to the Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario.

Mudroch, A., R.J. Allan and **S.R. Joshi**. 1989. Toxic chemicals in sediments of Great Slave Lake, Northwest Territories, Canada. NWRI Contribution 89-21.

Mudroch, A. and D. Williams. 1989. Distribution of the bottom sediments in the Niagara River. J. Great Lakes Res. In press.

Nagy, E., J.H. Carey and J.H. Hart. 1989. Hydrocarbons in Great lakes sediments. NWRI Contribution 89-01.

Nagy, E., J.H. Carey and E.D. Ongley. 1989. Under-ice hydrocarbons in the Mackenzie River. NWRI Contribution 89-10.

Nalewajko, C., C. Ewing and **A. Mudroch**. 1989. A comparison of the effects of sediments and standard elutriates on phosphorus kinetics in lake water. Water Air Soil Pollut. In press.

Reynoldson, T.B., D.W. Schloesser and B.A. Manny. 1989. Development of a benthic invertebrate objective for mesotrophic Great Lakes waters. NWRI Contribution 89-02.

Reynoldson, T.B. and M.A. Zarull. 1989. Biological assessment of contaminated sediments. The Detroit River example. NWRI Contribution 88-49.

Zeman, A.J. 1989. Numerical modelling of seepage erosion in shore bluffs consisting of glaciolacustrine silts. NWRI Contribution 89-03.

Air-Water Interactions

A/Project Chief

Dr. W.A. Glooschenko
B.S. (Berkeley), M.S. (Davis), Ph.D. (Oregon State)
biogeochemistry of wetlands and peat, and atmospheric transport of metals

Study Leaders

Dr. L.D. Delorme
B.Sc. (Saskatchewan), M.Sc. (Alberta), Ph.D. (Saskatchewan)
paleoclimatology and invertebrate ecology

Dr. R.F. Platford
B.Sc., M.Sc. (British Columbia), Ph.D. (Saskatchewan)
chemistry of radionuclides and thermodynamics of brines

W.M. Schertzer
B.A. (Windsor), M.Sc. (McMaster)
physical climatology and water quality modelling

Dr. M.R. Servos
B.Sc., M.Sc. (Guelph), Ph.D. (Manitoba)
environmental chemistry of organic contaminants

Dr. W.M.J. Strachan
B.A., M.A. (Toronto), Ph.D. (Queen's)
toxic organic contaminants in rain and aquatic systems

Professional and Technical Staff

D. Burnison, B.Sc. (McMaster);
N. Harper, B.S. (Allegheny)

PUBLICATIONS

Boyce, F.M., **W.M. Schertzer**, P.F. Hamblin and R. Murthy. 1989. An assessment of current understanding of the physical behaviour of Lake Ontario with reference to contaminant pathways and climate change. NWRI Contribution 89-23.

Delorme, L.D. 1989. Methods in quaternary ecology #7, freshwater ostracodes. Can. Geoscience 16: 85-90.

Eisenreich, S.J., W.A. Willford and **W.M.J. Strachan**. 1988. The role of atmospheric deposition in organic contaminant cycling in large lakes. *In* D. Allen [ed.] Intermedia Pollutant Transport: Modelling and Field Measurements. Plenum Press, New York, N.Y.

Glooschenko, W.A. 1988. Atmospheric deposition of arsenic and selenium across Canada using *Sphagnum* moss as a biomonitor. Sci. Tot. Env. 73: 269-275.

Glooschenko, W.A. 1989. *Sphagnum fuscum* moss as an indicator of atmospheric cadmium deposition across Canada. Environ. Pollution 57: 27-33.

Glooschenko, W.A. 1989. Wetland conservation in Latin America. Water Quality Bulletin 14: 81-87.

Glooschenko, W.A., I.P. Martini and K. Clarke-Whistler. 1988. Salt marshes of Canada. p. 347-377. *In* C.D.A. Rubec [ed.] Wetlands of Canada. Polyscience Publications, Montréal, Quebec.

Havel, J., P. Hebert and **L.D. Delorme**. Genetics of sexual Ostracoda from a low Arctic site. Evolution. In press.

McCrimmon, R.C., **W.M. Schertzer** and A.M. Sawchuk. 1988. Simulation of surface water temperature and ice extent in Lake Ontario and Lake Erie using a dynamic reservoir simulation model (DYRESM). NWRI Contribution 88-32.

Sawchuk, A.M. and **W.M. Schertzer**. 1988. Climatology of Lake Ontario and Lake Erie surface heat exchanges, 1953-1983. NWRI Contribution 88-37.

Servos, M.R., G.G. Choudhry and D.C.G. Muir. 1989. Methods for dissolving hydrophobic compounds in water: interactions with dissolved organic matter. p. 251-262. *In* I.H. Suffet and P. MacCarthy [eds.] Aquatic Humic Substances: Influence on Fate and Treatment of Pollutants. Advance in Chemistry, Series No. 219, American Chemical Society.

Servos, M.R. and D.C.G. Muir. 1989. Effect of dissolved organic matter from Canadian Shield lakes on the bioavailability of 1,3,6,8-tetrachlorodibenzo-p-dioxin to the amphipod *Crangonyx laurentianus*. Environ. Toxicol. Chem. 8: 141-150.

Servos, M.R. and D.C.G. Muir. 1989. The effect of suspended sediment concentration on the sediment to water partition coefficient for 1,3,6,8-tetrachlorodibenzo-p-dioxin. Environ. Sci. & Tech. In press.

Servos, M.R., D.C.G. Muir and G.R.B. Webster. 1989. The effect of dissolved and particulate organic matter on the bioavailability of polychlorinated dioxins. Aquat. Toxicol. 14: 169-184.

Servos, M.R., D.C.G. Muir, D.M. Whittle, D.B. Sergeant and G.R.B. Webster. 1989. Bioavailability of octachlorodibenzo-p-dioxin in aquatic ecosystems. Chemosphere. In press.

Simons, T.J. and **W.M. Schertzer**. 1989. The circulation of Lake Ontario during the summer of 1982 and the winter of 1982-83. Environment Canada, IWD Scientific Series 171.

Strachan, W.M.J. 1988. Polychlorinated biphenyls (PCBs)—Fate and effects in the Canadian environment. Environment Canada Report EPS 4/HA/2. 90 p.

Strachan, W.M.J. 1988. Atmospheric deposition of chemicals in Canada. *In* Symposium on Persistent Pesticides, 3rd North American Chemistry Congress, Toronto, Ontario, ACS-STP. In press.

Strachan, W.M.J. 1988. Moss bags as monitors of organic contamination in the atmosphere. Bull. Envir. Contam. Toxic. 40: 447-450.

Strachan, W.M.J. 1988. Test systems and exposure in the aquatic environment. Ambio 17: 394-397.

Strachan, W.M.J. 1988. Toxic chemicals in Canadian rainfall. *In* S. Hochheiser and R.K.M. Jayanty [eds.] Measurement of Toxic and Related Air Pollutants. Air Pollution Control Association Meeting, Raleigh, N.J., EPA 600/9-88-015.

Strachan, W.M.J. and S.J. Eisenreich. 1988. Mass balance accounting of chemicals in the Great Lakes. *In* Symposium on Persistent Pesticides, 3rd North American Chemistry Congress, Toronto, Ontario, ACS-STP. In press.

Strachan, W.M.J. and S.J. Eisenreich. 1988. Mass balance of toxic chemicals in the Great Lakes: the role of atmospheric deposition. Report to the Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario. 113 p.

Webster, G.R.B., **M.R. Servos**, G.G. Choudry and D.C.G. Muir. 1989. Methods for dissolving hydrophobic compounds in water: interactions with dissolved organic matter. p. 251-262. *In* I.H. Suffet and P. MacCarthy [eds.] Aquatic Humic Substances: Influence on Fate and Treatment of Pollutants. Advance in Chemistry, Series No. 219, American Chemical Society.

Westgate, J.A. and **L.D. Delorme**. 1988. Lacustrine ostracodes in the Late Pleistocene Sunnybrook diamicton of southern Ontario, Canada: Reply. Can. J. Earth Sci. 25: 1721-1723.

Nearshore-Offshore Interactions

Project Chief

Dr. K.L.E. Kaiser
B.Sc., M.Sc., Ph.D. (Technical Univ., Munich)
volatile trace contaminant analysis and QSAR

Study Leaders

Dr. E. Halfon
B.A. (Milan), Ph.D. (Georgia)
environmental modelling, simulation of contaminant pathways, ranking and decision making, and expert systems

Dr. P.F. Hamblin
B.Sc. (Toronto), M.Sc. (British Columbia),
Ph.D. (Washington)
dynamics and thermodynamics of lakes and reservoirs

Dr. K. Kwasniewska
B.Sc., M.Sc., Ph.D. (Marie Curie-Sklodowska)
environmental toxicity of yeast and fungi

Dr. C.R. Murthy
B.Eng. (Mysore), M.Eng. (Indian Institute of Science),
Ph.D. (Waterloo)
turbulent transport and diffusion processes in lakes

Dr. J.O. Nriagu
B.Sc. (Ibadan), M.S. (Wisconsin),
Ph.D. (Toronto), D.Sc. (Ibadan)
geochemistry, trace metals and sulphur in aquatic ecosystems

Professional and Technical Staff

R.D. Coker; M.E. Comba; H.F.H. Dobson;
K.C. Miners, B.A. (Western Ontario); D.G. Roberston, B.Sc. (Manitoba)

PUBLICATIONS

Boyce, F.M., M.A. Donelan, **P.F. Hamblin, C.R. Murthy** and J.T. Simons. 1988. Thermal structure and circulation in the Great Lakes. Atmosphere-Ocean. In press.

Boyce, F.M., **P.F. Hamblin**, F. Chiocchio and **D.G. Robertson**. 1989. Evaluation of sediment traps in Lake St. Clair, Lake Ontario and in Hamilton Harbour. NWRI Contribution 89-09.

Boyce, F.M., W.M. Schertzer, **P.F. Hamblin** and **R. Murthy**. 1989. An assessment of current understanding of the physical behaviour of Lake Ontario with reference to contaminant pathways and climate change. NWRI Contribution 89-23.

Carey, J.H. and **C.R. Murthy** [eds.]. 1988. Water pollution related research in the lower Fraser River, British Columbia. Water Poll. Res. J. Canada 23(1): 212 p.

Comba, M.E., V.S. Palabrica and **K.L.E. Kaiser**. 1989. St. Lawrence River trace organic contaminants study (Part I), 1985. NWRI Contribution 89-50.

Comba, M.E., V.S. Palabrica, J. Wasslen, G.A. Bengert and **K.L.E. Kaiser**. 1989. St. Lawrence River trace organic contaminants study (Part II), 1986. NWRI Contribution 89-51.

Gough, K.M. and **K.L.E. Kaiser**. 1988. QSAR of the acute toxicity of para-substituted nitrobenzene and aniline derivatives to *Photobacterium phosphoreum*. p. 111-121. *In* J.E. Turner, M.W. England, T.W. Schultz and N.J. Kwaak [eds.] Proceedings of the 3rd International Workshop on QSAR in Environmental Toxicology, May 22-26, 1988, Knoxville, Tennessee. National Technical Information Service, U.S. Dept. of Commerce, Springfield, Va., CONF. 880520.

Halfon, E. and R. Bruggeman. 1988. Environmental hazard of eight chemicals in the Rhine River. Wat. Sci. & Technol. 21: 815-820.

Halfon, E. and R. Bruggeman. 1988. Environmental hazard ranking of chemicals spilled in the Rhine River in November 1986. Acta Hydrochimica et Hydrobiologica 17: 47-60.

Halfon, E. and M. Reggiani. 1988. An improved ranking scheme for environmental hazard. p. 183-194. *In* Proceedings of the State-of-the-Art in Ecological Modelling, Venice, Italy, June 23- 30, 1987. Elsevier Science Publishers.

Halfon, E. 1989. Comparison of an index function and a vectorial approach for ranking water disposal sites. Environ. Sci. & Tech. 23: 600-609.

Halfon, E. 1989. Determination of optimal experimental conditions to validate toxic contaminants volatilization models. *In* B.P. Patten [ed.] Ecological Modelling in the Mid 1980s. Elsevier Science Publishers. In press.

Halfon, E. 1989. Microcomputers in ecological modelling: a special issue dedicated to research, education and computer graphics. Ecol. Model. In press.

Halfon, E. 1989. Modelling the fate of toxic contaminants in the aquatic environment: a review. *In* E. Doudou and F. Ribeyre [eds.] Aquatic Toxicology. CRC Press, Inc., Fla. In press.

Halfon, E. 1989. On the probabilistic validation of ecological models. Ecol. Model. In press.

Halfon, E. and D.M. deJong. 1989. A computer program to display animations within the computer graphics HALO environment. Ecol. Model. In press.

Halfon, E., H.A. Hodson and K. Miles. 1989. An algorithm to plot Hasse diagrams on microcomputers and Calcomp plotters. Ecol. Model. In press.

Halfon, E. and R. Oliver. 1989. Simulation and data analysis of four chlorobenzenes in a large lake system (Lake Ontario) with TOXFATE, a contaminant fate model. *In* S.E. Jorgensen [ed.] Advances in Ecological Modelling. Elsevier Science Publishers.

Hamblin, P.F. 1988. Observations and model of sediment transport near the turbidity maximum of the Upper St. Lawrence estuary. NWRI Contribution 88-42.

Hamblin, P.F., K.R. Lum, **M.E. Comba** and **K.L.E. Kaiser**. 1988. Observations of suspended sediment flux over a tidal cycle in the region of the turbidity maximum of the upper St. Lawrence River estuary. p. 245-256. *In* D.G. Aubrey and L. Weishar [eds.] Hydrodynamics and Sediment Dynamics of Tidal Inlets. Lecture Notes on Coastal Estuarine Studies, Vol. 29, Springer-Verlag, New York, N.Y.

Hamblin, P.F. 1989. Notes on the hydraulics of Hamilton Harbour. NWRI Contribution 89-36.

Hamblin, P.F. 1989. Yukon River headwater lakes study: observation and analyses. NWRI Contribution 89-55.

Hamblin, P.F., J.A. Bull and F. Chiocchio. 1989. A note on a microprocessor-based recording current meter suitable for wave research. NWRI Contribution 89-54.

Hamblin, P.F. and E.C. Carmack. 1989. On the rate of transfer of heat between a lake and an ice sheet. NWRI Contribution 89- 27.

Hodson, P.V., D.G. Dixon and **K.L.E. Kaiser**. 1988. Estimating the acute toxicity of waterborne chemicals in trout from measurements of median lethal dose and the octanol-water partition coefficient. Environ. Toxicol. Chem. 7: 443-454.

Kaiser, K.L.E. 1988. Comments on the 3rd International Workshop on QSAR in Environmental Toxicology. p. 217-220. *In* J.E. Turner, M.W. England, T.W. Schultz and N.J. Kwaak [eds.] Proceedings of the 3rd International Workshop on QSAR in Toxicology, May 22-26, 1988, Knoxville, Tennessee. National Technical Information Service, U.S. Dept. of Commerce, Springfield, Va., CONF. 880520.

Kaiser, K.L.E. 1988. Comments on the 31st Annual Conference on Great Lakes Research. J. Great Lakes Res. 14: 526-527.

Kaiser, K.L.E. 1988. Managing the Great Lakes: the need for an international research centre. J. Great Lakes Res. 14: 1.

Kaiser, K.L.E. and J.M. Ribo. 1988. *Photobacterium phosphoreum* toxicity bioassay. II. Toxicity data compilation. Toxicity Assessment 3: 195-237.

Kaiser, K.L.E., J.M. Ribo and **K. Kwasniewska**. 1988. Microtox survey of Lake St. Clair water. Water Poll. Res. J. Canada 23: 356-359.

Kenaga, D. and **K.L.E. Kaiser**. 1989. UGLCC Level III Synthesis Report on the Detroit River. Upper Great Lakes Connecting Channels Study, Final Report, Volume II, Chapter VII.

Kwasniewska, K. 1988. Horizontal distribution and density of yeasts and filamentous fungi in Lake St. Clair water. J. Great Lakes Res. 14: 438-443.

Lam, D.C.L., R.C. McCrimmon, J.H. Carey and **C.R. Murthy**. 1988. Modelling the transport and pathways of tetrachlorophenol in the Fraser River. Water Poll. Res. J. Canada 23: 141-159.

Nriagu, J.O. 1988. A silent epidemic of environmental poisoning? Environ. Pollut. 50: 139-161.

Nriagu, J.O. 1988. Historical perspectives on chromium. Adv. Environ. Sci. Tech. 20: 125-172.

Nriagu, J.O. 1988. Quantitative assessment of worldwide contamination of the air, water and soils with trace metals. Nature 333: 134-139.

Pacyna, J.M. and **J.O. Nriagu**. 1988. Atmospheric emissions of chromium from natural and anthropogenic sources. Adv. Environ. Sci. Tech. 20: 105-124.

Patterson, J.C. and **P.F. Hamblin**. 1988. Thermal simulation of lake with winter ice cover. Limnol. Oceanogr. 33: 323-338.

Lakes Restoration

Project Chief

M.N. Charlton
B.Sc., M.Sc. (Toronto)
limnology

Study Leaders

M.E. Fox
B.Sc. (Mount Allison)
toxic organics chemistry

Dr. M. Hanna
B.Sc. (Ottawa), M.Sc., Ph.D. (Toulouse)
limnology

Dr. P.G. Manning
B.Sc., Ph.D. (Wales)
geochemistry of iron and phosphorus

T. Mayer
M.Eng. (Slovak Technical Univ.), M.Sc. (McMaster)
geochemistry of iron and phosphorus

Dr. T.P. Murphy
B.Sc. (Queen's), M.Sc. (Toronto), Ph.D. (British Columbia)
restoration limnology

D.S. Painter
B.Sc., M.Sc. (Guelph)
aquatic plant studies

Dr. N.A. Rukavina
B.A. (Toronto), M.Sc. (Western Ontario), Ph.D. (Rochester)
sedimentology of freshwater sediments

Professional and Technical Staff

W.G. Booth;
Dr. L.L. Kalas, B.Sc., Ph.D. (Bratislava);
P.A. Thiessen

PUBLICATIONS

Babin, J.E., E.E. Prepas, **T.P. Murphy** and H.R. Hamilton. 1989. A test of the effects of lime on algal biomass and nutrient levels in Edmonton storm water retention lakes. NWRI Contribution 89-14.

Barica, J., D.J. Poulton, B. Kohli and **M.N. Charlton**. 1988. Water exchange between Lake Ontario and Hamilton Harbour: water quality implications. Water Poll. Res. J. Canada 23: 213-226.

Carey, J.H., **M.E. Fox** and J.H. Hart. 1988. Identity and distribution of chlorophenols in the north arm of the Fraser River estuary. Water Poll. Res. J. Canada 23: 31-44.

Carey, J.H., **M.E. Fox** and L.P. Schleen. 1988. Photodegradation of the lampricide 3-trifluoromethyl-4-nitrophenol (TFM). 2. Field confirmation of direct photolysis and persistence of formulation impurities in a stream during treatment. J. Great Lakes Res. 14: 338-346.

Coakley, J.P. and **N.A. Rukavina**. 1989. Nearshore bedload and suspended sediment transport in the vicinity of Pickering Nuclear Generating Station, Lake Ontario. NWRI Contribution 89-17.

Coakley, J.P., M.G. Skafel, R.G.D. Davidson-Arnott, A.J. Zeman and **N.A. Rukavina**. 1988. Computer simulation of nearshore profile evolution in cohesive materials. NWRI Contribution 88-25.

Fox, M.E. 1988. Rapid determination of chlorophenols in sediments. *In* Proceedings of the XXth Annual Eastern Canada Workshop on Pesticide Residues and Environmental Contaminants, Sault Ste. Marie, Ontario, June 1988.

Fox, M.E., D.S. Roper and S.F. Thrush. 1988. Organochlorine contaminants in the surficial sediments of Manukau Harbour, New Zealand. Mar. Pollut. Bull. 19: 333-336.

Fox, M.E. and R.J. Wilcock. 1988. Soil, water and vegetation residues of 2,4,5-T applied to a New Zealand hillside. N.Z. J. Agr. Res. 31: 347-357.

Fox, M.E. and J.H. Carey. 1989. Dynamics of plume dispersion of 1,2,3,4-tetrachlorobenzene from the Niagara River into Lake Ontario. NWRI Contribution 89-52.

Hanna, M. 1989. Biologically available phosphorus: estimation and prediction using an anion-exchange resin. Can. J. Fish. Aquat. Sci. In press.

Lim, J.T., E.E. Prepas, **T.P. Murphy** and D.T. Walty. 1989. Evaluation of $CaCO_3$ and $Ca(OH)_2$ as algicides in Prairie drinking water dugouts. NWRI Contribution 89-13.

Maguire, R.J., J.H. Carey, **M.E. Fox**, B.G. Brownlee and H.B. Lee. 1988. Assessment of the environmental dynamics of selected pesticides of importance in Western Canada. NWRI Contribution 88-20.

Manning, P.G., **T.P. Murphy**, **T. Mayer** and E. Prepas. 1988. Effect of copper sulfate on pyrite formation in reducing sediments. Can. Mineral. 26: 965-972.

Mayer, T. and **P.G. Manning**. 1989. Inorganic contaminants in suspended solids from Hamilton Harbour. NWRI Contribution 89-12.

Mayer, T. and **P.G. Manning**. 1989. Variability of phosphorus forms in suspended solids at Lake Erie-Grand River confluence. J. Great Lakes Res. In press.

Metcalfe, J.L., **M.E. Fox** and J.H. Carey. 1988. Freshwater leeches (Hirudinea) as a screening tool for detecting organic contaminants in the environment. Environ. Monit. Assess. 11: 147-169.

Metcalfe, J.L. and **M.N. Charlton**. 1989. Freshwater mussels as biomonitors for organic industrial contaminants and pesticides in the St. Lawrence River. NWRI Contribution 89-60.

Murphy, T.P., K.G. Hall and T.G. Northcote. 1988. Lime treatment of a hardwater lake to reduce eutrophication. Lake and Reservoir Management 4: 51-62.

Painter, S., **T.P. Murphy** and D. Boyd. 1989. Contamination of bottom sediments in Hamilton Harbour. NWRI Contribution 89-25.

Prepas, E.E. and **T.P. Murphy**. 1988. Sediment-water interactions in farm dugouts previously treated with copper sulfate. Lake and Reservoir Management 4: 161-169.

Prepas, E.E., **T.P. Murphy**, J.M. Crosby, D.T. Walty, J.T. Lim, J. Babin and P.A. Chambers. 1989. The reduction of phosphorus, iron and chlorophyll *a* concentrations following $CaCO_3$ and $Ca(OH)_2$ additions to hypereutrophic Figure Eight Lake, Alberta. Environ. Sci. & Tech. In press.

Rodgers, G.K., J. Vogt, V. Cairns, D. Boyd, L. Simser, C. Selby, H. Lang, **T.P. Murphy** and **S. Painter**. 1989. Remedial Action Plan for Hamilton Harbour. Stage 1: Environmental Conditions and Problem Definitions. 160 p.

Ward, P.R.B., E.A. Cousins, K.J. Hall, T.G. Northcote and **T.P. Murphy**. 1989. Mixing by wind and penetrative convection in small lakes. NWRI Contribution 89-34.

Ward, P.R.B., K.J. Hall, T.G. Northcote, W. Cheung and **T.P. Murphy**. 1989. Autumnal mixing in Mahoney Lake, British Columbia. NWRI Contribution 89-33.

RIVERS RESEARCH BRANCH

Director's Office

Director

Dr. E.D. Ongley
B.A. (Toronto), Ph.D. (Sydney)
geomorphology and land-water interactions

Senior Scientist

Dr. R.L. Thomas
B.Sc., Ph.D. (Wales)
sedimentology and geochemistry

A/Science Liaison Coordinators

Dr. M. Allard
B.Sc. (Québec à Montréal), Ph.D. (Laval)
limnology and benthic ecology

J. Legault
B.Sc. (Laval), M.Sc. (Québec)
environmental chemistry

PUBLICATIONS

Burrus, D., **R.L. Thomas**, J. Dominik and J.-P. Vernet. 1988. Recovery and concentration of suspended solids in the Upper Rhône River by continuous flow centrifugation. Hydrological Processes 3: 65-74.

Day, K.E., **E.D. Ongley**, R.P. Scroggins and H.R. Eisenhauer [eds.]. 1988. Biology in the New Regulatory Framework for Aquatic Protection. Proceedings of the Alliston Workshop, April 26-28, 1988. Environment Canada Report No. EN 37-88/1988E, 71 p.

Day, K.E., **E.D. Ongley**, R.P. Scroggins and H.R. Eisenhauer. 1988. Biology in the new regulatory framework for aquatic protection: major messages and recommendations from the Alliston Workshop, April 26-28, 1988. p. 103-108. *In* Proceedings of the 15th Aquatic Toxicity Workshop, Montréal, Quebec, November 28-30, 1988.

Droppo, I.G. and **E.D. Ongley**. 1989. Flocculation of suspended solids in southern Ontario rivers. p. 91-100. *In* R.F. Hadley and E.D. Ongley [eds.] Sediment and the Environment. IAHS Publ. No. 184.

Hadley, R.F. and **E.D. Ongley** [eds.]. 1989. Sediment and the Environment. Proceedings of Symposium on Sediment and the Environment. Int. Assoc. Hydrol. Sci., 3rd Scientific Assembly, May 17-18, 1988, Baltimore, Md. IAHS Publ. No. 184.

Hartig, J. and **R.L. Thomas**. 1988. The development of plans for the restoration of degraded areas in the Great Lakes. Environ. Manage. 12: 327-347.

Munawar, M. and **R.L. Thomas**. 1988. Phytoplankton bioassays of sediment from two Areas of Concern in the North American Great Lakes: Toronto (Ontario) and Toledo (Ohio) harbours. *In* Proceedings of the Fourth International Symposium on the Interaction Between Sediment and Water, Melbourne, Australia. In press.

Nagy, E., J.H. Carey and **E.D. Ongley**. 1989. Under-ice hydrocarbons in the Mackenzie River. NWRI Contribution 89-10.

Ongley, E.D. 1988. Aquatic protection: a national workshop. Environment Canada NWRI Digest 3: 1.

Ongley, E.D., S. Beltaos, D.C.L. Lam and J. Marsalek. 1988. Models for river basin management. Water for World Development, Volume III—Agriculture, Irrigation and Drainage; Environment. p. 378-387. *In* Proceedings of the 6th IWRA World Congress on Water Resources, May 29-June 3, 1988, Ottawa, Canada.

Ongley, E.D. and **R.L. Thomas**. 1989. Dewatering suspended solids by continuous-flow centrifugation: practical considerations. Hydrological Processes. In press.

Thomas, R.L. 1988. Evaluation of anthropogenic impacts through lake sediments. Chapter 18. *In* Global Environmental Assessment, WHO, UNESCO.

Thomas, R.L. 1988. Lake case study: the Great Lakes. Chapter 15. *In* Global Environmental Assessment, WHO, UNESCO.

River Modelling

Project Chief

Dr. S. Beltaos
Dipl. Civ. Eng. (Athens), M.Sc., Ph.D. (Alberta), P.Eng.
river ice studies

Study Leaders

Dr. B.G. Brownlee
B.Sc., M.Sc. (Alberta), Ph.D. (New Brunswick)
taste and odour compounds, and water quality analysis

Dr. R.P. Bukata
B.Sc., M.Sc., Ph.D. (Manitoba)
aquatic optics and satellite studies

Dr. B.G. Krishnappan
B.E. (Madras), M.Sc. (Calgary), Ph.D. (Queen's), P.Eng.
river dynamics

Dr. Y.L. Lau
B.A.Sc., M.A.Sc., Ph.D. (Toronto), P.Eng.
river dynamics

J. Marsalek
Dipl. Eng., Cand. Tech. Sci. (Prague), P.Eng.
urban hydrology

Dr. G. Tsang
B.E., M.Eng.Sc. (New South Wales), Ph.D. (Waterloo), P.Eng.
ice studies

Professional and Technical Staff

J.E. Bruton, B.Sc. (McMaster); J.H. Jerome, B.Eng. (McMaster);
G.A. MacInnis, B.Sc. (P.E.I.);
H.Y.F. Ng, B.Sc. (Taiwan), M.Sc. (Southampton), P.Eng.

PUBLICATIONS

Anderson, J.E., L.D. Bungay, **S. Beltaos** and I.K. Hill. 1988. Ice-related flooding on Harry's River. p. 369-391. *In* Proceedings of the 5th Workshop on Hydraulics of River Ice/Ice Jams, Winnipeg, Manitoba.

Beltaos, S. 1988. Configuration and properties of a breakup jam. Can. J. Civ. Eng. 15: 685-697.

Beltaos, S. 1988. Current North American trends in river ice research. p. 3-29. *In* Proceedings of the Nordic Expert Meeting on River Ice, Espoo, Finland.

Beltaos, S. 1988. Primer on hydraulics of river ice. Chapter 4: Breakup, Ice Jams and Related Flooding. NWRI Contribution 88-97.

Beltaos, S. 1988. The monograph on river ice jams. p. 1-14. *In* Proceedings of the 5th Workshop on Hydraulics of River Ice/Ice Jams, Winnipeg, Manitoba.

Beltaos, S. and V. Arora. 1988. An explicit algorithm to simulate transient transverse mixing in rivers. Can. J. Civ. Eng. 15: 964-976.

Beltaos, S. 1989. New Brunswick River Ice Manual. Chapter 5: Predictive methods. NWRI Contribution 89-66.

Boom, A. and **J. Marsalek**. 1988. Accumulation of polycyclic aromatic hydrocarbons (PAHs) in an urban snowpack. Sci. Tot. Env. 74: 133-148.

Brownlee, B.G., L. Gammie, W.D. Gummer and **G.A. MacInnis**. 1988. A simple extraction procedure for moderately volatile taste and odour compounds such as geosmin and 2-methylisoborneol. Method and applications. Water Sci. & Technol. 20: 91-97.

Bruton, J.E., R.P. Bukata and J.H. Jerome. 1988. The concept of onshore colonization efficiency in evaluating the impact on marshlands of persistent water level increases. NWRI Contribution 88-98.

Bruton, J.E., J.H. Jerome and **R.P. Bukata**. 1988. Satellite observations of sediment transport patterns in the Lac Saint-Pierre region of the St. Lawrence River. Water Poll. Res. J. Canada 23: 243-252.

Bukata, R.P., J.E. Bruton, J.H. Jerome and W.S. Haras. 1988. An evaluation of the impact of persistent water level changes on the extent of Georgian Bay/North Channel marshlands. Environ. Manage. 12: 359-368.

Bukata, R.P., J.E. Bruton, J.H. Jerome and W.S. Haras. 1988. A mathematical description of the effects of prolonged water level fluctuations on the areal extent of marshlands. Environment Canada, IWD Scientific Series No. 166.

Bukata, R.P., J.H. Jerome and **J.E. Bruton**. 1988. Determination of irradiation and primary production using a time-dependent attenuation coefficient. NWRI Contribution 88-85.

Bukata, R.P., J.H. Jerome and **J.E. Bruton**. 1988. Particulate concentrations in Lake St. Clair as recorded by a shipborne multispectral optical monitoring system. Remote Sens. Environ. 25: 201-229.

Bukata, R.P., J.H. Jerome and **J.E. Bruton**. 1988. Relationships among Secchi disk depth, beam attenuation coefficient and irradiance attenuation coefficient for Great Lakes waters. J. Great Lakes Res. 14: 347-355.

Edsall, T.A., J.J. Dawson, **R.P. Bukata**, R.H. Brock, I.J. Horvath and W.J. Christie. 1988. Inventory techniques applicable to habitat classification of lakes. Special publication, Great Lakes Fish. Comm., Ann Arbor, Mich. In press.

Jerome, J.H., R.P. Bukata and **J.E. Bruton**. 1988. Determination of scalar irradiation available for photolysis in natural waters. NWRI Contribution 88-88.

Jerome, J.H., R.P. Bukata and **J.E. Bruton**. 1988. Utilizing the components of vector irradiance to estimate the scalar irradiance in natural waters. Applied Optics 27: 4012-4018.

Kovacz, G., F.C. Zuidema and **J. Marsalek**. 1988. Human interventions in the terrestrial water cycle. Chapter 5, p. 105-130. *In* T. Chapman and M. Falkenmark [eds.] Comparative Hydrology. UNESCO Press, Paris.

Lau, Y.L. 1988. Hydraulic resistance of ripples. J. Hydraul. Eng., ASCE, 114: 1275-1282.

Lau, Y.L. 1989. Modelling biofilm consumption in open channel flow. NWRI Contribution 89-69.

Lau, Y.L., B.G. Oliver and **B.G. Krishnappan**. 1989. Transport of some chlorinated contaminants by the water, suspended sediments and bed sediments in the St. Clair and Detroit rivers. Environ. Toxicol. Chem. 8: 293-301.

Maguire, R.J., J.H. Carey, M.E. Fox, **B.G. Brownlee** and H.B. Lee. 1988. Assessment of the environmental dynamics of selected pesticides of importance in Western Canada. NWRI Contribution 88-20.

Marsalek, J. 1988. Considerations of manhole head losses in pressurized sewer flow routing. 6 p. *In* Proceedings of International Symposium on Urban Hydrology and Municipal Engineering, Toronto, Ontario, June 13-15, 1988.

Marsalek, J. 1988. Evaluation of pollution loads from urban nonpoint sources. p. 1-22. *In* Proceedings of the International Joint Commission Miniworkshop on Nonpoint Sources of Urban Pollution, Windsor, Ontario, October 1988.

Marsalek, J. 1988. Head losses at sewer junctions. Chapter 9, p. 191-216. *In* P.N. Cheremisinoff, N.P. Cheremisinoff and S.L. Chang [eds.] Civil Engineering Practice. Techomic Publishing Co. Inc., Lancaster-Basel.

Marsalek, J. 1988. Integrated water management in urban areas. Urban Water '88, Invited Lectures volume. F1-F12. *In* Proceedings of the UNESCO International Symposium on Hydrological Processes and Water Management in Urban Areas, Duisburg, West Germany, April 24-28, 1988.

Marsalek, J. and B.J. Greck. 1988. Head losses at manholes with a 90° bend. Can. J. Civ. Eng. 15: 851-858.

Marsalek, J. and B.J. Steinback. 1988. Hydraulic modelling off low measurement structures. p. 21-26. *In* Preprints of the 1988 Environment Conference, Vancouver, B.C., October 25-27, 1988.

Marsalek, J. and H. Schroeter. 1989. Annual loadings of toxic contaminants in urban runoff from the Canadian Great Lakes Basin. Water Poll. Res. J. Canada 23: 360-378.

Ng, H.Y.F. and **J. Marsalek**. 1989. Simulation of the effects of urbanization on basin streamflow. Water Resour. Bull. 25: 117- 124.

Ng, H.Y.F. and **J. Marsalek**. 1989. Storm water discharges to Hamilton Harbour. NWRI Contribution 89-67.

Ongley, E.D., **S. Beltaos**, D.C.L. Lam and **J. Marsalek**. 1988. Models for river basin management. Water for World Development, Volume III—Agriculture, Irrigation and Drainage; Environment. p. 378-387. *In* Proceedings of the 6th IWRA World Congress on Water Resources, May 29-June 3, 1988, Ottawa, Canada.

Tsang, G. 1988. A theory for frazil distribution in turbulent flow. Vol. 2, p. 152-169. *In* Proceedings of the 9th IAHR Ice Symposium, Sapporo, Japan, August 23-27, 1988.

Tsang, G. 1988. Development of mathematical modelling for prediction of river cooling and frazil and anchor ice formation. p. 393-416. *In* Proceedings of 5th Workshop on Hydraulics of River Ice, NRCC, June 22-24, 1988, Winnipeg, Manitoba.

Wong, J., **S. Beltaos** and W. Moody. 1988. SYG-ICE: a model material for river ice breakup studies. NWRI Contribution 88-86.

Contaminants-Pesticides

Project Chief

Dr. R.J. Maguire
B.Sc. (Ottawa), Ph.D. (Alberta)
fate of industrial organic compounds and pesticides in water

Study Leaders

Dr. Y.K. Chau
B.Sc. (Lingnan), M.Sc. (Hong Kong), Ph.D., D.Sc. (Liverpool)
fate and effects of metals in contaminated areas

Dr. K.E. Day
B.Sc., M.Sc. (Waterloo), Ph.D. (Guelph)
bioaccumulation and effects of organic contaminants on invertebrates

Dr. D.L.S. Liu
B.Sc. (Taiwan Chung-Hsin)
M.Sc., Ph.D. (British Columbia)
biodegradation of organic contaminants

Dr. K.R. Lum
B.Sc. (Manitoba), Ph.D. (Liverpool)
biogeochemistry of trace elements

J.L. Metcalfe
B.Sc. (Manitoba)
biomonitoring techniques for contaminants in aquatic ecosystems

Professional and Technical Staff

S.P. Batchelor, B.Sc. (Toronto); G.A. Bengert, B.Sc. (McMaster); R.J. Tkacz, B.Sc. (Western Ontario); H.K.T. Wong, B.Sc. (Waterloo)

PUBLICATIONS

Chau, Y.K. 1988. Speciation of molecular and ionic organometallic compounds in biological samples. Sci. Tot. Env. 71: 57-58.

Chau, Y.K., P.T.S. Wong, **G.A. Bengert** and J. Wasslen. 1988. Bioaccumulation of alkyllead compounds from water and from contaminated sediment. J. Appl. Organomet. Chem. 2: 427-433.

Day, K.E., E.D. Ongley, R.P. Scroggins and H.R. Eisenhauer. 1988. Biology in the new regulatory framework for aquatic protection: major messages and recommendations from the Alliston Workshop, April 26-28, 1988. p. 103-108. *In* Proceedings of the 15th Aquatic Toxicity Workshop, Montréal, Quebec, November 28-30, 1988.

Day, K.E., E.D. Ongley, R.P. Scroggins and H.R. Eisenhauer [eds.]. 1988. Biology in the New Regulatory Framework for Aquatic Protection. Proceedings of the Alliston Workshop, April 26-28, 1988. Environment Canada Report No. EN 37-88/1988E, 71 p.

Day, K.E. 1989. Acute, chronic and sublethal effects of synthetic pyrethroids on freshwater zooplankton. Environ. Toxicol. Chem. In press.

Day, K.E. 1989. Pesticide residues in freshwater and marine zooplankton. *In* T.S.S. Dikshith [ed.] Handbook of Pesticide Residues in Animals and the Environment. CRC Press, Inc., Florida. In press.

Day, K.E., **J.L. Metcalfe** and **S.P. Batchelor**. 1989. Changes in intracellular free amino acids in gill, mantle and adductor tissue of caged mussels exposed to stressful environments. NWRI Contribution 89-104.

Green, R.H., R.C. Bailey, S.G. Hinch, **J.L. Metcalfe** and V. Young. 1989. The use of unionid clams to monitor the nearshore environment of lakes. J. Great Lakes Res. In press.

Hamblin, P.F., **K.R. Lum**, M.E. Comba and K.L.E. Kaiser. 1988. Observations of suspended sediment flux over a tidal cycle in the region of the turbidity maximum of the upper St. Lawrence River estuary. p. 245-256. *In* D.G. Aubrey and L. Weishar [eds.] Hydrodynamics and Sediment Dynamics of Tidal Inlets. Lecture Notes on Coastal Estuarine Studies, Vol. 29. Springer-Verlag, New York, N.Y.

Liu, D.L.S. 1989. A rapid and simple biochemical test for direct determination of chemical toxicity. Toxicity Assessment. In press.

Liu, D.L.S. 1989. Assessment of the interaction between microorganism and chemical mixture using resazurin reduction. Toxicity Assessment. In press.

Liu, D.L.S. 1989. Biodegradation of pentachlorophenol and its commercial formulation. Toxicity Assessment 4: 115-128.

Liu, D.L.S., **Y.K. Chau** and B.J. Dutka. 1989. Rapid toxicity assessment of water-soluble and water-insoluble chemicals using a modified agar plate method. Water Res. In press.

Maguire, R.J., J.H. Carey, M.E. Fox, B.G. Brownlee and H.B. Lee. 1988. Assessment of the environmental dynamics of selected pesticides of importance in Western Canada. NWRI Contribution 88-20.

Maguire, R.J. and **R.J. Tkacz**. 1988. Chlorinated hydrocarbons in the surface microlayer and subsurface water of the Niagara River, 1985-86. Water Poll. Res. J. Canada 23: 292-300.

Maguire, R.J. 1989. Research on pesticides at the National Water Research Institute. *In* Proceedings of the Workshop on Agricultural Chemicals and Water Quality in Ontario, Kitchener, November 17-18, 1988, sponsored by the Ontario Water Management Research and Services Committee. In press.

Maguire, R.J. 1989. Spectral characterization of some dyestuffs used in the Eastern Townships of Quebec. NWRI Contribution 89-77.

Maguire, R.J., J.H. Carey, J.H. Hart, **R.J. Tkacz** and H.B. Lee. 1989. Persistence and fate of deltamethrin sprayed in a pond. J. Agric. Food Chem. In press.

Martin, R.C., D.G. Dixon, **R.J. Maguire**, P.V. Hodson and **R.J. Tkacz**. 1989. Acute toxicity, uptake, depuration and tissue distribution of tri-n-butyltin in rainbow trout (*Salmo gairdneri*). Aquat. Toxicol. In press.

Metcalfe, J.L., M.E. Fox and J.H. Carey. 1988. Freshwater leeches (Hirudinea) as a screening tool for detecting organic contaminants in the environment. Environ. Monit. Assess. 11: 147-169.

Metcalfe, J.L. and M.N. Charlton. 1989. Freshwater mussels as biomonitors for organic industrial contaminants and pesticides in the St. Lawrence River. NWRI Contribution 89-60.

Metcalfe, J.L. and A. Hayton. 1989. Comparison of leeches and mussels as biomonitors for chlorophenol pollution. J. Great Lakes Res. In press.

Tian, S., **Y.K. Chau** and **D.L.S. Liu**. 1989. Biodegradation of bis(tri-n-butyltin) oxide. J. Appl. Organomet. Chem. 3. In press.

Weng, J.-H. and **R.J. Maguire**. 1989. Photodegradation of the dyestuff Disperse Blue 26 in water. NWRI Contribution 89-61.

Wong, P.T.S., **Y.K. Chau**, J. Yaromich, P. Hodson and M. Whittle. 1988. Alkyllead contamination in the St. Lawrence and St. Clair rivers (1981-87). Can. Tech. Rep. Fish. Aquat. Sci. No. 1602, 134 p.

Long Range Transport of Airborne Pollutants (LRTAP)

Project Chief

Dr. D.C.L. Lam
B.Sc.(Hong Kong), M.A.Sc., Ph.D. (Waterloo)
contaminant transport and watershed modelling

Study Leaders

A.G. Bobba
B.Sc. (Vikram), M. Tech. (Ravishankar), M.S. (Ohio State)
hydrogeology and contaminant modelling

Dr. W.G. Booty
B.Sc. (Waterloo), M.Sc., Ph.D. (McMaster)
watershed geochemical modelling

Dr. R.A. Bourbonniere
B.A. (Northeastern), M.S., Ph.D. (Michigan)
organic geochemistry

Dr. A.H. El-Shaarawi
B.Sc., M.Sc. (Cairo), Ph.D. (Waterloo)
statistical modelling

A.S. Fraser
B.Sc. (Waterloo)
water quality and LRTAP modelling

R.G. Semkin
B.Sc. (Toronto), M.Sc. (McMaster)
geochemical processes controlling water acidification

Professional and Technical Staff

J.L. Jones, B.Sc. (Memorial); R. Neureuther;
F. Norouzian, B.Sc. (McMaster); M.D. Seymour;
I. Wong, B.A.Sc., M.A.Sc. (Waterloo)

PUBLICATIONS

Bobba, A.G. 1988. Acid deposition—soil acidification: literature review. NWRI Contribution 88-109.

Bobba, A.G. and S.R. Joshi. 1988. Groundwater transport of radium-226 and uranium from Port Granby waste management site to Lake Ontario. Nucl. Chem. Waste Manage. 8: 199-209.

Bobba, A.G. and **D.C.L. Lam**. 1988. Application of a hydrological model to the acidified Turkey Lakes Watershed. Can. J. Fish. Aquat. Sci. 45: 81-87.

Booty, W.G., J.V. DePinto and R.D. Scheffe. 1988. Drainage basin control of acid loadings to two Adirondack lakes. Water Resour. Res. 24: 1024-1036.

Bourbonniere, R.A. 1989. Distribution patterns of dissolved organic matter fractions in natural waters from Eastern Canada. Organic Geochem. In press.

Bourbonniere, R.A. 1989. Geochemistry of dissolved organic matter in brownwaters from Atlantic Canada. *In* Proceedings of the Applied Aquatic Studies Workshop, Edmonton, Alberta, February 21-22, 1989. In press.

Castillo, R., R. Thiers, B.J. Dutka and **A.H. El-Shaarawi**. 1988. Coliphage association with coliform indicators: a case study in Chile. Toxicity Assessment 3: 535-550.

Damsleth, E. and **A.H. El-Shaarawi**. 1989. ARIMA models with double exponentially distributed noise. J. Royal Statistical Society Ser. B 51: 61-69.

DePinto, J.V., **W.G. Booty**, R.D. Scheffe and T.C. Young. 1989. Predicting reacidification of calcite-treated acid lakes. Can. J. Fish. Aquat. Sci. 46: 323-332.

Dolan, D.M. and **A.H. El-Shaarawi**. 1989. Inferences about point source loadings from upstream/downstream river monitoring data. Environ. Monit. Assess. In press.

El-Shaarawi, A.H. 1989. Inferences about the mean from censored water quality data. Water Resour. Res. 25: 685-690.

El-Shaarawi, A.H. and D.M. Dolan. 1989. Maximum likelihood estimation of water quality concentrations from censored data. Can. J. Fish. Aquat. Sci. 46: 1033-1039.

El-Shaarawi, A.H., P.B. Kauss and M. Kirby. 1989. Statistical analysis of Niagara River biomonitoring data. Environ. Monit. Assess. In press.

Esterby, S.R., **A.H. El-Shaarawi**, G.D. Howell and T.A. Clair. 1988. Detailed results of the stratification of sets of Nova Scotia and Newfoundland lakes. NWRI Contribution 89-24.

Jeffries, D.S., **R.G. Semkin**, **R. Neureuther** and **M.D. Seymour**. 1988. Ion mass budgets for lakes in the Turkey Lakes Watershed, June 1981-May 1983. Can. J. Fish. Aquat. Sci. 45: 47-58.

Joshi, S.R. and **A.G. Bobba**. 1988. Finite element modelling of transport Ra-226 and U from a radioactive waste management site to Lake Ontario. p. 193-200. *In* G. Desmet [ed.] Reliability of Radioactive Transfer Models. Elsevier Science Publishers.

Lam, D.C.L., **A.G. Bobba**, D.S. Jeffries and D. Craig. 1988. Modelling stream chemistry for the Turkey Lakes Watershed: comparison with 1981-84 data. Can. J. Fish. Aquat. Sci. 45: 72- 80.

Lam, D.C.L., **A.S. Fraser**, D.A. Swayne, J. Storey and I. Wong. 1988. Regional analysis of watershed acidification using the expert systems approach. Environ. Software 3: 127-134.

Lam, D.C.L., R.C. McCrimmon, J.H. Carey and C.R. Murthy. 1988. Modelling the transport and pathways of tetrachlorophenol in the Fraser River. Water Poll. Res. J. Canada 23: 141-159.

Lam, D.C.L., D.A. Swayne, **A.H. El-Shaarawi** and J. Storey. 1988. Water quality data management (Malaysia/Canada) from RAISON/acid rain to RAISON/water quality. Report to IDRC, File No. 3-P-86-1051-01, Ottawa, Canada, 9 p.

Lam, D.C.L., D.A. Swayne, J. Storey, **A.S. Fraser** and I. Wong. 1988. Regional analysis of watershed acidification using the expert systems approach. 15 p. *In* Proceedings of the Workshop on the Application of Artificial Intelligence (expert systems) in Environment Canada, Ottawa, Canada, June 21-22, 1988.

Lam, D.C.L., I. Wong, D.A. Swayne, Z. Novak and S. Klose. 1988. Impact assessment of mine effluent by the expert system approach. 1988 Fall Meeting of American Geophysical Union, San Francisco, Calif. EOS 69: 1226.

Lam, D.C.L., G. Howell, D.A. Swayne, **A.S. Fraser**, J. Storey and I. Wong. 1989. A knowledge-based approach to regional acidification modelling: a case study of New Brunswick, Canada. *In* Proceedings of the Aulanko Meeting on Acidification Models, Finnish MOE, Helsinki, Finland, July 5-8, 1988. In press.

Martins, M.T., **A.H. El-Shaarawi**, P.S. Sanchez and B.J. Dutka. 1988. Coliphage association with coliform indicators: a case study in Brazil. Toxicity Assessment. In press.

Ongley, E.D., S. Beltaos, **D.C.L. Lam** and J. Marsalek. 1988. Models for river basin management. Water for World Development, Volume III—Agriculture, Irrigation and Drainage; Environment. p. 378-387. *In* Proceedings of the 6th IWRA World Congress on Water Resources, May 29-June 3, 1988, Ottawa, Canada.

Ratto, A., **A.H. El-Shaarawi**, B.J. Dutka, C. Lopez and C. Vega. 1988. Coliphage association with coliform indicators: a case study in Peru. Toxicity Assessment 3: 519-534.

Semkin, R.G. and D.S. Jeffries. 1988. Chemistry of atmospheric deposition, the snowpack and snowmelt in the Turkey Lakes Watershed. Can. J. Fish. Aquat. Sci. 45: 38-46.

Swayne, D.A., **D.C.L. Lam**, **A.S. Fraser**, J. Storey, I. Wong and Y. Ando. 1988. Regional assessment of lake acidification by expert systems. 1988 Fall Meeting of American Geophysical Union, San Francisco, Calif. EOS 69: 1226.

Thompson, M.E. and **A.H. El-Shaarawi**. 1988. On the estimation of phosphorus loading to Lake Ontario from the Niagara River. Environ. Monit. Assess. In press.

Vet, R.J., A. Sirois, D.S. Jeffries, **R.G. Semkin**, N.W. Foster, P. Hazlett and C.H. Chan. 1988. Comparison of bulk, wet-only, and wet-plus-dry deposition measurements of the Turkey Lakes Watershed. Can. J. Fish. Aquat. Sci. 45: 26-37.

Ecotoxicology

Project Chief

B.J. Dutka
B.A., M.Sc. (Queen's)
microbiological methods and toxicity screening

Study Leaders

K.K. Kwan
B.A. (Lakehead)
microbiology and toxicity screening tests

Dr. S.S. Rao
B.Sc., Ph.D. (Mysore)
particulates and fluvial contaminant transport

Professional and Technical Staff

K. Jones, B.Sc. (McMaster); A.A. Jurkovic; R. McInnis; P. Stewart

PUBLICATIONS

Castillo, G., R. Theirs, **B.J. Dutka** and A.H. El-Shaarawi. 1988. Coliphage association with coliform indicators: a case study in Chile. Toxicity Assessment 3: 535-550.

Dutka, B.J. 1988. Proposed ranking scheme and battery of tests for evaluating hazards in Canadian waters and sediments. NWRI Contribution 88-80.

Dutka, B.J., K. Jones, K.K. Kwan, H. Bailey and **R. McInnis**. 1988. Use of microbial and toxicant screening tests for priority site selection of degraded areas in water bodies. Water Res. 22: 503-510.

Dutka, B.J. and **K.K. Kwan**. 1988. Battery of screening tests approach applied to sediment extracts. Toxicity Assessment 3: 303-314.

Dutka, B.J., D. Munro, P. Seidl, C. Lauten and **K.K. Kwan**. 1988. Use of a battery of biological tests to assess aquatic quality in Canadian Prairie and northern watersheds. NWRI Contribution 88-107.

Dutka, B.J. and **S.S. Rao**. 1988. Microbiological and toxicological studies of streams. p. 90-98. *In* J. Fitzgibbon and P. Mason [eds.] Managing Ontario Streams. Canadian Water Resource Association, Cambridge, Ontario.

Dutka, B.J., T. Tuominen, L. Churchland and **K.K. Kwan**. 1988. Fraser River sediments and waters evaluated by the battery of screening tests technique. NWRI Contribution 88-84.

El-Abagy, M.M., **B.J. Dutka** and M. Kamel. 1988. Incidence of coliphage in potable water supplies. Appl. Environ. Microbiol. 54: 1632-1633.

Liu, D.L.S., Y.K. Chau and **B.J. Dutka**. 1989. Rapid toxicity assessment of water-soluble and water-insoluble chemicals using a modified agar plate method. Water Res. In press.

Martins, M.T., A.H. El-Shaarawi, P.S. Sanchez and **B.J. Dutka**. 1988. Coliphage association with coliform indicators: a case study in Brazil. Toxicity Assessment. In press.

Martins, M.T., V.H. Pellazari, G.M.D.D. Colletto and **B.J. Dutka**. 1988. "Metodos simplificadus e rapidos para o exame microbiologico da aqua." *In* Proceedings of the "21st Congresso Interamericano de Engenharia Sanitaria e Ambiencial," Rio de Janeiro, September 18-23, 1988.

Rao, S.S. 1988. *Ceriodaphnia reticulata* seven-day survival and reproduction test. Toxicity Assessment 3: 239-244.

Rao, S.S., H.G. Thode and M.D. Dickman. 1988. Isotopic and diatom evidence of bacterial sulphate reduction. NWRI Contribution 88-16.

Rao, S.S., J.H. Weng and B.G. Krishnappan. 1988. Particle associated contaminant transport in the Yamaska River. NWRI Contribution 88-104.

Ratto, A., A.H. El-Shaarawi, **B.J. Dutka**, C. Lopez and C. Vega. 1988. Coliphage association with coliform indicators: a case study in Peru. Toxicity Assessment 3: 519-534.

Groundwater Contamination

Project Chief

Dr. R.E. Jackson
B.S. (Arizona State), M.A.Sc. (Ottawa), Ph.D. (Waterloo)
migration and fate of contaminants in groundwater

Study Leaders

Dr. A.S. Crowe
B.Sc. (Waterloo), M.Sc., Ph.D. (Alberta)
groundwater and geochemical modelling

Dr. S. Lesage
B.Sc. (Ottawa), Ph.D. (McGill)
chemistry of groundwater contaminants

K.S. Novakowski
B.Sc. (Brock), M.Sc. (Waterloo)
hydrogeology of fractured rocks

Professional and Technical Staff

P.A. Lapcevic, B.Sc. (Waterloo); M.W. Priddle, B.Sc. (Waterloo)

PUBLICATIONS

Crowe, A.S., R.E. Jackson, S. Lesage and **M.W. Priddle**. 1988. Contamination of groundwater from the Gloucester Landfill at the Ottawa International Airport. 15 p. *In* Proceedings of the Environmental Workshop '88: Environmental Issues at Federal Facilities. Transport Canada Workshop, September 19-23, 1988, Winnipeg, Manitoba.

Jackson, R.E., A.S. Crowe, S. Lesage and **M.W. Priddle**. 1988. Aquifer contamination and restoration at the Gloucester Landfill, Ontario, Canada. NWRI Contribution 88-96.

Jackson, R.E. 1989. The *in situ* adsorption of Sr-90 in a sand aquifer at the Chalk River Nuclear Laboratories. J. Contaminant Hydrology 4: 27-50.

Jackson, R.E., S. Lesage and **M.W. Priddle**. 1989. Sampling and analysis of ground water quality at hazardous waste sites in Eastern Canada. *In* Proceedings of the NHRI Symposium on Ground Water Contamination, Saskatoon, Saskatchewan. In press.

Jackson, R.E. and R.J. Patterson. 1989. A remedial investigation of an organically polluted outwash aquifer. Ground Water Monitoring Review. In press.

Lesage, S. and Y. Stokker. 1988. Aldicarb residues in water: a perspective. p. 57-62. *In* K.M.S. Sundaram [ed.] Proceedings of the 20th Annual Eastern Canada Workshop on Pesticides Residues and Environmental Contaminants, May 31-June 3, 1988, Sault Ste. Marie, Ontario.

Lesage, S. 1989. Solid phase sample collection for the analysis of aldicarb residues in groundwater. LC-GC 7: 268-271.

Lesage, S., R.E. Jackson, M.W. Priddle and P. Riemann. 1989. Occurrence and fate of organic solvent residues in anoxic groundwater. NWRI Contribution 89-65.

Novakowski, K.S. 1988. A computer program to generate type curves for well testing problems in fractured rock. J. Ground Water. In press.

Novakowski, K.S. 1988. Comparison of fracture aperture widths determined from hydraulic measurements and tracer experiments. *In* Proceedings of the Fourth Canadian/American Conference on Hydrogeology, Banff, Alberta. In press.

Novakowski, K.S. and J.A. Cherry. 1988. Evaluating groundwater velocity in a low-permeability fractured shale. p. 273-282. *In* Proceedings of the Technology Transfer Conference, Ontario Ministry of the Environment, Toronto, Ontario.

Novakowski, K.S., J.A. Cherry and R.W. Gillham. 1988. Field methodology in preparing for and conducting a natural gradient tracer experiment in a discrete fracture. EOS 69: 1186.

Novakowski, K.S. and **P.A. Lapcevic**. 1988. Regional hydrogeology of the Silurian and Ordovician sedimentary rock underlying Niagara Falls, Ontario. J. Hydrol. 104: 211-236.

Novakowski, K.S. 1989. A composite analytical model for analysis of pumping tests affected by wellbore storage and finite thickness skin. Water Resour. Res. In press.

Webber, M.D. and **S. Lesage**. 1989. Organic contaminants in Canadian municipal sludges. Waste Management & Research 7: 63- 82.

RESEARCH AND APPLICATIONS BRANCH

Director's Office

Director
Dr. J. Lawrence
B.Sc., Ph.D. (Bristol)
analytical chemistry and quality assurance

A/Science Liaison Coordinator
J.F. Ryan

PUBLICATIONS

Lawrence, J. 1988. Research and Applications Branch Annual Study Report 1987-88. NWRI Contribution 88-69.

Lawrence, J., K.I. Aspila and A.S.Y. Chau. 1988. Metrological quality assurance in environmental measurements. *In* Proceedings of the 2nd Symposium on Metrological Assurance for Environmental Control, August 22-24, 1988, Helsinki University of Technology, Otaniemi, Espoo, Finland.

Lawrence, J. 1989. Humic acid and related substances in the environment. p. 313-337. *In* B.K. Afghan and A.S.Y. Chau [eds.] Analysis of Trace Organics in the Aquatic Environment. CRC Press Inc., Boca Raton, Fla.

Kohli, J., **J.F. Ryan** and B.K. Afghan. 1989. Phthalate esters in the aquatic environment. p. 243-281. *In* B.K. Afghan and A.S.Y. Chau, [eds.] Analysis of Trace Organic in the Aquatic Environment. CRC Press Inc., Boca Raton, Fla.

Analytical Chemistry

Project Chief
Dr. I. Sekerka
RNC, RNDr. (Prague), CSc. (Ostrava)
electroanalytical chemistry and flow injection analysis

Study Leaders
Dr. B.K. Afghan
B.Sc. (Sind), D.I.C. (I.C., London), Ph.D. (London)
column liquid chromatography, gas chromatography and liquid chromatography-mass spectrometry

D.H. Anthony
B.Sc. (McMaster)
plasma spectrometry and sample preconcentration

Dr. V. Cheam
B.S., Ph.D. (Oklahoma)
ion chromatography and atomic spectroscopy

Dr. S.A. Daniels
B.S., M.S. (Louisiana State), Ph.D. (Waterloo)
biochemical mechanisms of toxicity and electrokinetic analysis

Dr. H.B. Lee
B.Sc. (Hong Kong), Ph.D. (McMaster)
gas chromatography, mass spectrometry and
high pressure liquid chromatography

Dr. F.I. Onuska
P.Chem.Eng. (Bratislava), M.Sc. (Prague), CSc. (Brno), Ph.D. (Waterloo)
gas chromatography and mass spectrometry

Dr. B.F. Scott
B.Sc., M.A., Ph.D. (Toronto)
broad spectrum analysis

Dr. J.P. Sherry
B.Sc., Ph.D. (N.U.I., Dublin)
immunoassay screening

Professional and Technical Staff
J.F. Lechner; K.A. Terry; R.J. Wilkinson

PUBLICATIONS

Afghan, B.K. and A.S.Y. Chau [eds.]. 1989. Analysis of Trace Organics in the Aquatic Environment. CRC Press Inc., Boca Raton, Fla., 346 p.

Carron, J.M. and **B.K. Afghan**. 1989. Environmental aspects and analysis of phenols in the aquatic environment. p. 119-149. *In* B.K. Afghan and A.S.Y. Chau [eds.] Analysis of Trace Organics in the Aquatic Environment. CRC Press Inc., Boca Raton, Fla.

Cheam, V., K.I. Aspila and A.S.Y. Chau. 1988. Analytical Reference Materials. VIII. Development and certification of a new Great Lakes sediment reference material for eight trace metals. NWRI Contribution 88-71.

Cheam, V., A.S.Y. Chau and W. Horn. 1988. National Interlaboratory Quality Control of Study No. 35—Trace metals in sediments. Environment Canada, Inland Waters Directorate, Report Series No. 76.

Cheam, V. and E Xue Li. 1988. Ion chromatographic determination of low level Cd(II), Co(II) and Mn(II) in water. J. Chromatogr. 450: 361-371.

Cheam, F. and E Xue Li. 1988. Ion exchange-spectrophotometric determination of ppb and sub-ppb Cd. Am. Chem. Soc., Div. Envir. Chem. 28: 416-420.

Clement, R.E., **F.I. Onuska**, G.A. Eiceman and H.H. Hill, Jr. 1988. Gas chromatography. Anal. Chem. 60: 279R-294R.

Kohli, J., J.F. Ryan and **B.K. Afghan**. 1989. Phthalate esters in the aquatic environment. p. 243-281. *In* B.K. Afghan and A.S.Y. Chau [eds.] Analysis of Trace Organics in the Aquatic Environment. CRC Press Inc., Boca Raton, Fla.

Lee, H.B. 1988. Perfluoro and chloro amide derivatives of aniline and chloroanilines. J. Chromatogr. 457: 267-278.

Lee, H.B., R. Hong-You and P.J.A. Fowlie. 1988. Chemical derivatization analysis of phenols. VI. Determination of chlorinated phenolics in pulp and paper effluents. NWRI Contribution 88-110.

Lee, H.B., E.A. Kokotich and J.A. Abbott. 1988. Determination and confirmation of some synthetic pyrethroids and their metabolites in water samples. NWRI Contribution 88-70.

Lee, H.B. and G.D. Kissoon. 1989. Determination and confirmation of chloronitrobenzenes in water and fish samples. NWRI Contribution 89-81.

Li, W.C., **H.B. Lee** and A.S.Y. Chau. 1988. Organic standards for preparation of blind spikes. NWRI Contribution 88-64.

Maguire, R.J., J.H. Carey, M.E. Fox, B.G. Brownlee and **H.B. Lee**. 1988. Assessment of the environmental dynamics of selected pesticides of importance in Western Canada. NWRI Contribution 88-20.

Maguire, R.J., J.H. Carey, J.H. Hart, R.J. Tkacz and **H.B. Lee**. 1989. Persistence and fate of deltamethrin sprayed in a pond. J. Agric. Food Chem. In press.

Niimi, A.J., **H.B. Lee** and G.D. Kissoon. 1989. Octanol-water partition coefficients and bioconcentration factors of chloronitrobenzenes in rainbow trout (*salmo gairdneri*). Environ. Toxicol. Chem. In press.

Oliver, B.G., R.M. Baxter and **H.B. Lee**. 1989. Polychlorinated biphenyls. p. 31-68. *In* B.K. Afghan and A.S.Y. Chau [eds.] Analysis of Trace Organics in the Aquatic Environment. CRC Press Inc., Boca Raton, Fla.

Onuska, F.I. and **K.A. Terry**. 1988. Identification and quantitative analysis of nitrogen-containing polycyclic aromatic hydrocarbons in sediments. NWRI Contribution 88-79.

Onuska, F.I. and **K.A. Terry**. 1988. Supercritical fluid extraction of 2,3,7,8-tetrachloro dibenzo-p-dioxin from sediment samples. J. High Resolut. Chromatogr. Chromatogr. Commun. In press.

Onuska, F.I. 1989. Analysis of polycyclic aromatic hydrocarbons in environmental samples. p. 205-241. *In* B.K. Afghan and A.S.Y. Chau [eds.] Analysis of Trace Organics in the Aquatic Environment. CRC Press Inc., Boca Raton, Fla.

Onuska, F.I. 1989. Techniques and procedures for preparation of aquatic samples for chromatographic analysis. J. High Resolut. Chromatogr. Chromatogr. Commun. 12: 4-11.

Scott, B.F. 1988. Analysis of PCBs and organochlorines by dual column capillary gas chromatography. p. 53. *In* Proceedings of the 23rd Annual Workshop for Pesticide and Trace Organic Residue Analysis, April 27-28, Regina, Saskatchewan.

Scott, B.F. and M. Misunis. 1988. Enhanced gas chromatographic quantitation of organochlorines. NWRI Contribution 88-11.

Scott, B.F., F.I. Onuska and J. Kohli. 1988. Determination of polychlorinated biphenyls and organochlorines by dual column gas chromatography. NWRI Contribution 88-78.

Scott, B.F. and **F.I. Onuska**. 1989. Analysis for polychlorinated biphenyls by dual capillary column gas chromatography. The Journal of Microcolumn Separations. In press.

Sekerka, I., J.S. Ford, **J.F. Lechner** and X.M. Sheikh. 1988. Determination of acid neutralizing capacity of water and related problems. Int. J. Environ. Anal. Chem. In press.

Sekerka, I. and **J.F. Lechner**. 1988. Determination of alkalinity of water by FIA with conductometric detection. NWRI Contribution 88-68.

Sekerka, I. and **J.F. Lechner**. 1989. Automated method for the determination of boron in water. Analyst. In press.

Sekerka, I. and **J.F. Lechner**. 1989. Instruction manual for determination of Ca and Mg by flow detection analysis and atomic absorption spectroscopy. NWRI Contribution 89-94.

Sergeant, P.B. and **F.I. Onuska**. 1989. Analysis of toxaphene in environmental samples. p. 69-118. *In* B.K. Afghan and A.S.Y. Chau [eds.] Analysis of Trace Organics in the Aquatic Environment. CRC Press Inc., Boca Raton, Fla.

Sherry, J.P., B.K. Afghan, J. ApSimon, L. Collier, F. Bishai and P.W. Albro. 1989. Radioimmunoassay for the detection of polychlorinated dibenzo-p-dioxins in environmental samples: introduction, preliminary evaluation, and development of a working assay. NWRI Contribution 89-80.

Sherry, J.P., J. ApSimon, L. Collier, **B.K. Afghan** and P.W. Albro. 1988. Radioimmunoassay for the detection of polychlorinated dibenzo-p-dioxins in environmental samples: method description. NWRI Contribution 88-73.

Sherry, J., J. ApSimon, L. Collier, **R. Wilkinson**, P.W. Albro and **B.K. Afghan**. 1988. The use of radioimmunoassay for the detection of polychlorinated dibenzo-p-dioxins in fish samples. NWRI Contribution 88-76.

Sherry, J.P. 1989. A comparison of the abilities of 15 media to recover viable yeasts from pond, river and lake water. J. Microbiological Methods. In press.

Tse, H., J. Carron, M. Forbes and **H.B. Lee**. 1989. A multi-residue method for the determination of chlorobenzenes, PCB, organochlorinated insecticides, PAH, and chlorophenols in suspended sediments. NWRI Contribution 89-82.

Hydraulics

Project Chief

Dr. M.G. Skafel
B.A., B.E., M.Sc. (Saskatchewan), Ph.D. (Cambridge), P.Eng.
coastal engineering

Study Leaders

C.T. Bishop
B.Sc., M.Sc. (Queen's), P.Eng.
coastal engineering

Dr. M.A. Donelan
B.Eng. (McGill), Ph.D. (British Columbia)
air-water interaction

P. Engel
B.A.Sc., M.A.Sc. (Waterloo), P.Eng.
fluvial engineering

Technical Staff

W.B. Taylor, Head, Technical Services Section;
D. Beesley; C. Bil; J. Dalton; D. Doede; G. Duncan;
F. Dunnett; D. Fekyt; J. Heidt; W. Moody; B. Near;
T. Nudds; R. Stephens; B. Trapp; G. Voros

PUBLICATIONS

Bishop, C.T. 1988. Historical variation of water levels in lakes Erie and Michigan-Huron. NWRI Contribution 88-72.

Bishop, C.T. 1988. Water levels. *In* J.W. Kamphuis [ed.] A Lecture In: Coastal Engineering Basics. Queen's University, Kingston, Ontario.

Bishop, C.T. 1988. Wave prediction. *In* J.W. Kamphuis [ed.] A Lecture In: Coastal Engineering Basics. Queen's University, Kingston, Ontario.

Bishop, C.T. and J.P. Coakley. 1989. Discussion of: stratigraphy of the Sixteen Mile Creek lagoon and its implications for Lake Ontario water levels by J.E. Flint, R.W. Dalrymple and J.J. Flint. Can. J. Earth Sci. In press.

Bishop, C.T. and **M.A. Donelan**. 1988. Waves and wave forecasting. p. 653-695. *In* P.N. Cheremisinoff, N.P. Cheremisinoff and S.L. Cheng [eds.] Civil Engineering Practice, Vol. 3. Geotechnical/Ocean Engineering, Technomic Publishing, Lancaster, Penn.

Bishop, C.T. and **M.A. Donelan**. 1989. Wave prediction models. *In* V.C. Lakhan [ed.] Coastal Modelling: Techniques and Applications. Elsevier Science Publishers. In press.

Boyce, F.M., **M.A. Donelan**, P.F. Hamblin, C.R. Murthy and J.T. Simons. 1988. Thermal structure and circulation in the Great Lakes. Atmosphere-Ocean. In press.

Coakley, J.P., **M.G. Skafel**, R.G.D. Davidson-Arnott, A.J. Zeman and N.A. Rukavina. 1988. Computer simulation of nearshore profile evolution in cohesive materials. NWRI Contribution 88- 25.

Donelan, M.A. and W.H. Hui. 1988. Mechanics of ocean surface waves. *In* G.L. Geernaert and W.J. Plant [eds.] Surface Waves and Fluxes: Current Theory and Remote Sensing. D. Reidel Publishing Co. In press.

Donelan, M.A. 1989. Air-sea interaction. *In* B. LeMehaute and D.M. Hanes [eds.] The Sea (9). Ocean Engineering Science, Wiley Interscience. In press.

Engel, P. 1988. Laboratory tests of artificial control for the Milk River—Phase I. NWRI Contribution 88-90.

Engel, P. and D. Doede. 1988. Stage discharge equations for sharp crested composite weirs. NWRI Contribution 88-75.

Engel, P. 1989. Preliminary examination of the variability in the towing carriage speed. NWRI Contribution 89-89.

Engel, P., Y.L. Lau and M. Spitzer. 1989. Effects of bed level fluctuations on discharge measurement in alluvial streams. NWRI Contribution 89-88.

Merzi, N., E.A. Terray and **M.A. Donelan**. 1988. Energy dissipation just beneath the air-water interface and consequences for gas transfer. NWRI Contribution 88-77.

Nece, R.E., E.E. Nelson and **C.T. Bishop**. 1988. Some North American experiences with floating breakwaters. *In* Proceedings of Breakwaters '88, Thomas Telford Ltd., London, U.K.

Wong, J., S. Beltaos and **W. Moody**. 1988. SYG-ICE: a model material for river ice breakup studies. NWRI Contribution 88-86.

Quality Assurance

Project Chief

A.S.Y. Chau
B.Sc. (British Columbia), M.Sc. (Carleton)
reference materials and quality assurance

Study Leaders

H. Alkema
B.T. (Ryerson)
federal/provincial quality assurance program and preservation

K.I. Aspila
B.Sc., M.Sc. (Carleton)
quality assurance

Y. Stokker
B.Sc. (Guelph), M.Sc. (Queen's)
organic methods development and quality assurance

Professional and Technical Staff

N. Arafat, B.Sc. (Waterloo)

PUBLICATIONS

Afghan, B.K. and **A.S.Y. Chau** [eds.]. 1989. Analysis of Trace Organics in the Aquatic Environment. CRC Press Inc., Boca Raton, Fla., 346 p.

Alkema, H. 1988. Summary report for the interlaboratory federal/provinical quality assurance program for inorganics in surface waters, Studies 19-30, July 1987-June 1988. NWRI Contribution 88-74.

Alkema, H. 1989. Summary report for the Prairie provinces quality assurance program for inorganics in surface waters, Studies 61-72, September 1987-August 1988. NWRI Contribution 89-86.

Allama, H. 1989. Summary report for the interlaboratory federal/provincial quality assurance program for inorganics in surface waters, Studies 21-32, September 1987-August 1988. NWRI Contribution 89-87.

Aspila, K.I. 1988. On comparability studies. *In* Proceedings of the 2nd Ecological Quality Assurance Workshop, February 8-10, 1988, Environmental Research Centre, University of Nevada, Las Vegas, Nev.

Cheam, V., **K.I. Aspila** and **A.S.Y. Chau**. 1988. Analytical Reference Materials. VIII. Development and certification of a new Great Lakes sediment reference material for eight trace metals. NWRI Contribution 88-71.

Cheam, V., **A.S.Y. Chau** and W. Horn. 1988. National Interlaboratory Quality Control of Study No. 35—Trace metals in sediments. Environment Canada, Inland Waters Directorate, Report Series No. 76.

Lawrence, J., **K.I. Aspila** and **A.S.Y. Chau**. 1988 Metrological quality assurance in environmental measurements. *In* Proceedings of the 2nd Symposium on Metrological Assurance for Environmental Control, August 22-24, 1988, Helsinki University of Technology, Otaniemi, Espoo, Finland.

Lesage, S. and **Y. Stokker**. 1988. Aldicarb residues in water: a perspective. p. 57-62. *In* K.M.S. Sundaram [ed.] Proceedings of the 20th Annual Eastern Canada Workshop on Pesticides Residues and Environmental Contaminants, May 31-June 3, 1988, Sault Ste. Marie, Ontario.

Li, W.C., H.B. Lee and **A.S.Y. Chau**. 1988. Organic standards for preparation of blind spikes. NWRI Contribution 88-64.

Stokker, Y.D. 1988. Method for the analysis of acid and neutral herbicides in sediments. NWRI Contribution 88-67.

RESEARCH SUPPORT DIVISION

Chief
J.D. Smith, C.D.

Engineering Services

A/Head
J.A. Bull, B.Eng. (McMaster)
limnological instrumentation

Engineers
R.J. Desrosiers, B.A.Sc., M.A.Sc. (Toronto)
electro-optics

J.S. Ford, B.A.Sc. (British Columbia), P.Eng.
scientific instrumentation design

N. Madsen, B.Sc. (Waterloo), P.Eng.
mechanical systems design

F.E. Roy, B.Sc., M.Sc. (McMaster), P.Eng.
scientific equipment design

J. Valdmanis, B.Eng. (McMaster), M.Sc. (Waterloo)
scientific instrumentation design

Technical Staff
W.J. Cooper; J.A. Diaz; J. Dolanjski;
J.G. Ford; K.K. Kalter; M.F. Kerman;
M. Pedrosa; L.R. Peer; H.A. Savile;
E.G. Smith; J.A. Tyler

Computing and Programming Services

Head
R.A. Duffield, B.Sc., M.B.A. (McMaster)
computer and programming services

Computer Applications
G.S. Beal; J.W. Byron;
H.E. Comba, B.Sc. (Carleton);
J.E. Dowell, B. Math. (Waterloo);
B. Hanson, B.A. (McMaster);
J.M. Hodson, B.Sc. (McMaster);
K. Miles; B. Ventresca, B.Sc. (Brock);
J. Young; A. Zingaro, B.Sc. (McMaster)

Computer Services
H.C. Pulley, B.Sc. (British Columbia);
C. Bell; U. Hamilton;
M. Kinder; B. Malseed

Drafting Services
M.L. Donnelly; W.D. Finn; K. Logan;
P. McColl; J. Van Nynatten

Technical Operations

A/Head
P.M. Healey

Technical Staff
L.E. Benner; G.D. Bruce; T.J. Carew;
Y. Desjardins; F.H. Don;
H.E. Greencorn; R.J. Hess; K.J. Hill;
W.D. Hunt; J.A. Kraft; G.G. LaHaie;
L.L. Lomas; M.R. Mawhinney;
B.H. Moore; S.B. Smith; J.E. Tozer;
E.H. Walker; P.R. Youakim

PUBLICATIONS

Hamblin, P.F., **J.A. Bull** and F. Chiocchio. 1989. A note on a microprocessor-based recording current meter suitable for wave research. NWRI Contribution 89-54.

Sekerka, I. **J.S. Ford**, J.F. Lechner and X.M. Sheikh. 1988. Determination of acid neutralizing capacity of water and related problems. Int. J. Environ. Anal. Chem. In press.

SCIENCE LIAISON DIVISION

SCIENCE LIAISON DIVISION

Chief
Dr. R.J. Daley
B.A., M.Sc., Ph.D. (Queen's)
limnology and microbial ecology

Senior Scientist, NWRI
Dr. R.A. Vollenweider
B.S., Ph.D. (Zurich), D.Sc. h.c. (McGill)
eutrophication of fresh and marine waters
(retired October 1988)

Senior Advisor, Research Management
Dr. G.K. Rodgers
B.A.Sc. (Toronto), M.Sc. (British Columbia), Ph.D. (Toronto)
engineering physics, physics, physical oceanography and limnology

Manager, WHO Collaborating Centre on Surface and Groundwater Quality
Dr. S. Barabas
B.S., Ph.D. (Padua)
physical chemistry

Library Services
E. Dowie, Head
B.A. (Regina), B.L.S., M.L.S. (Toronto)

PUBLICATIONS

Rodgers, G.K., J. Vogt, V. Cairns, D. Boyd, L. Simser, C. Selby, H. Lang, T.P. Murphy and S.Painter. 1989. Remedial Action Plan for Hamilton Harbour. Stage 1: Environmental Conditions and Problem Definitions. 160 p.

JOURNAL EDITORSHIPS

Allan, R.J.
Editor-in-chief, *Water Pollution Research Journal of Canada*

Barabas, S.
Editor-in-chief, *WHO Water Quality Bulletin*

Dutka, B.J. and **Lui, D.L.S.**
Co-Editors-in-chief, *Toxicity Assessment*

Nriagu, J.O.
Editor-in-chief, *Advances in Environmental Sciences & Technology*

Environment Canada Environnement Canada

Canada